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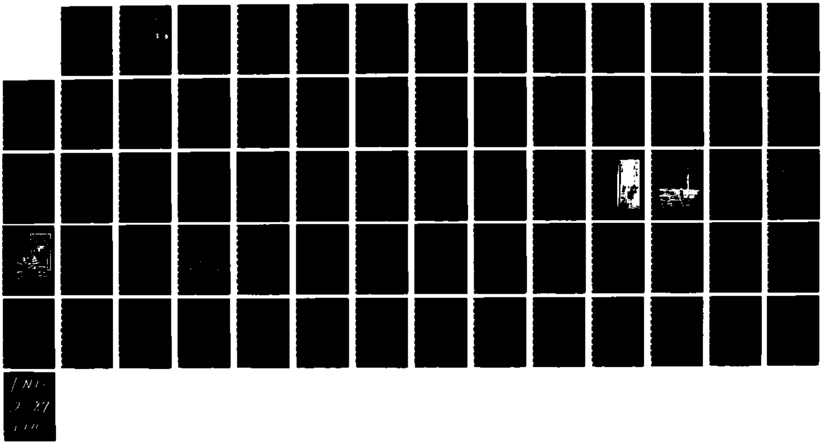

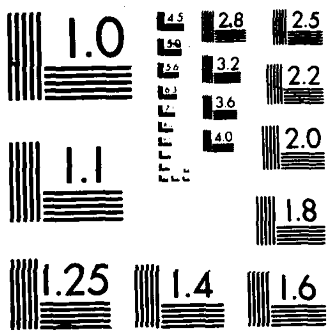

CROCOPY RESOLUTION TEST CHART

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DOT/FAA/PM-86/30
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FAA TECHNICAL CENTER
Atlantic City Airport
N.J. 08405

AD-A175 232

The Siting, Installation, and Operational Suitability of the Automated Weather Observing System (AWOS) at Heliports

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August 1986

Final Report

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16. Abstract

An Automated Weather Observing System (AWOS) was installed at the Federal Aviation Administration (FAA) Technical Center's Interim Concept Development Heliport. This was done in order to evaluate the siting, installation, and operational suitability of the AWOS at a heliport. The principal recommendations of this report have been incorporated in FAA Advisory Circular (AC) 150/5220-16, Automated Weather Observing Systems (AWOS) for Non-Federal applications.

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EXECUTIVE SUMMARY

During late 1985, flight tests were conducted at the Federal Aviation Administration (FAA) Technical Center. The flight tests were designed to develop siting standards for the Automated Weather Observing System (AWOS) when the equipment is sited at heliports. Additionally, data were collected to determine the operational suitability of AWOS equipment when installed at heliports.

The results of this testing have been incorporated into the FAA's Advisory Circular (AC) 150/5220-16 for siting of AWOS equipment in non-federal applications. The significant results showed that the wind sensors could be located as close as 75 feet to the center of the landing area when the sensor was 20 to 30 feet above the height of the landing area. Additionally, all AWOS equipment can be consolidated and occupy less than 20 square feet of surface area.

Operationally, no modifications of AWOS equipment are needed to support helicopter operators at heliports. However, due to limited real estate at most heliports a forward scatter visiometer should be used instead of a back scatter device. Necessary maintenance criteria for equipment installed at heliports were also determined.

1. INTRODUCTION.

The Federal Aviation Administration (FAA) Technical Center was tasked to site, install, and evaluate an Automated Weather Observing System (AWOS) at a heliport. The purpose of this document is to report the conclusions of the evaluation of the AWOS at the Technical Center's Interim Concept Development Heliport.

2. PURPOSE.

By using the AWOS equipment installed at the Interim Concept Development Heliport, in conjunction with literature research, the following test objectives were addressed:

a. Identified locations in the vicinity of the heliport in which helicopter operations could influence the environment causing transient AWOS sensor performance.

b. Identified areas for sensor location near the heliport that provided the most beneficial information to the pilot.

c. Determined optimal sensor location in relationship to predominant approach and departure paths.

d. Developed siting criteria and recommendations for AWOS equipment installation at heliports.

e. Determined the operational suitability of the AWOS equipment for heliport installations.

f. Identified additional maintenance requirements for the AWOS as the result of heliport installation.

3. BACKGROUND.

The AWOS incorporates a variety of automatic sensors which continuously detect and report cloud cover and height, visibility, precipitation occurrence and accumulation, wind speed, direction and character (gusting, variable direction), altimeter setting, density altitude, ambient temperature, and dewpoint temperature. It disseminates this information to the users via various media, including computer generated voice.

Due to the value of weather information, the installation of the AWOS equipment at a heliport is important and desirable. The Guidance and Airborne Systems Branch, ACT-140, Engineering Division, was tasked by APM-650 to site and install an AWOS at the Technical Center's Interim Concept Development Heliport. The resulting siting, installation, and operational suitability recommendations have been used to support FAA siting criteria of AWOS at heliports.

4. FACILITIES AND INSTRUMENTATION.

The following AWOS demonstration equipment (preproduction model) was installed at the Interim Concept Development Heliport at the Technical Center:

a. Ceilometer
b. Wind speed/direction sensor
c. Temperature and dewpoint sensors, with radiation shield
d. Rain gauge and wind screen
e. Backscatter visibility sensor
f. Barometric pressure sensors
g. Day/Night detector
h. Junction boxes
i. Very high frequency (VHF) data link equipment
j. Central processing unit

The AWOS provides meteorlogical observations once each minute.

Functional descriptions of the various sensors and data timing algorithms are included in appendix A.

5. SITE SELECTION AND INSTALLATION.

To install the AWOS, a site was selected 195 feet from the center of the landing pad and abeam the leading edge, relative to the instrument approach course at the heliport. The 195-foot distance was the result of the theoretical analysis of wind pressure data presented in Schwartz, Witczak and Leaky (1984). This site, theoretically, places the sensors outside rotor effects for aircraft with rotor diameters and gross weights similiar to the UH-1H and S-76. (These aircraft are modern single main rotor helicopters with rotor diameters of 44 to 48 feet and gross weights between 8,500 and 10,000 pounds.)

This site reflected the best compromise of the following requirements:

a. It avoided obstructing the predominant approach/departure path.

b. It was located near the heliport to simulate the siting limitations imposed by limited real estate.

c. It provided flexibility in approach path selection.

d. It met Terminal Instrument Procedures (TERPS), FAA Handbook 8260.3b, and Advisory Circular (AC) 150 Heliport Design Guide (Draft).

e. It was, theoretically, unaffected by rotor effects when the helicopter is centered on the heliport.

f. It was accessible to existing power supplies.

Four concrete pads were poured conforming to Uniform Building Code standards. The ceilometer was installed on one pad. The rain/snow gauge with wind screen

mounted on a wood platform was installed on the second pad. The backscatter visibility sensor was mounted on the third and a tower containing the remainder of the equipment (temperature and dew point sensor, anemometer, radiation shield, obstruction lights, and lightning protection) on the last pad. A pictorial layout of the equipment is presented in appendix B-2. This installation required an area of 140 square feet. (With changes in the design of the AWOS layout, the area required can be reduced to 36 square feet.)

6. TEST PROCEDURES.

6.1 HELIPORT MANEUVERING PROCEDURES.

Using a UH-1H helicopter, heliport maneuvering tests were conducted at four different heights: 5, 10, 20, and 25 feet above ground level. The aircraft was centered over three touchdown offset distances used for testing (measured from the center of the AWOS): 75, 105, and 195 feet. Due to the 2-minute running average used to calculate wind speed direction, a 3-minute hover was conducted at each hover height and touchdown offset combination. The wind sensor was placed at 11 feet above ground level (AGL) for these test flights. This phase was carried out prior to approach/departure path tests to determine the effect that hovering aircraft would have on the anemometer (wind sensor).

6.2 EXTENDED GROUND RUN TESTING.

These tests were conducted to determine any influence on the AWOS sensors by a helicopter hovering for an extended time period in one spot. Since some elements in the AWOS sequence report are based on fading memory filtering (data up to 10 minutes old), this test was conducted in an attempt to identify possible long term time constant effects on the AWOS performance. The extended ground run tests were conducted by two test pilots over a 2-day period using the S-76. The aircraft was flown at 100 percent main rotor revolutions per minute (rpm). The rotor disc was about 17 feet (5-foot hover height above the heliport) for 12.5 minutes. This procedure was repeated at each of the five touchdown offset distances. The 105 through 195-foot offset tests were carried out in 1 day, the 75-foot offset test was completed the following day. The 105-foot test was repeated as a backup to the previous day's results.

6.3 APPROACH/DEPARTURE PATH TESTING PROCEDURES.

The approach/departure path testing was conducted in the following manner. For two wind sensor heights of 15 and 30 feet, and temperature sensor heights of 5 and 10 feet, 23 separate approaches were flown to the helipad in the S-76. The flightpaths consisted of six different approach courses which were flown for up to five different touchdown offset distances. The six approach courses used in the test were: 24°, 54°, 84°, 114°, 324°, and 354° magnetic. The five touchdown distances were 75, 105, 135, 165, and 195 feet from the center of the AWOS site. These five offset termination points were marked by color-coded wooden stakes set at the five respective distances.

The 354°, 324°, and 24° approaches were flown to all five touchdown offsets. The 54° and 114° approaches each were flown to only the 135, 165, and the 195-foot touchdown distances, while the 84° approach was flown to only the 165 and 195-foot touchdown offsets. The closer offsets were not used with the approach courses which overflew the AWOS site. Five FAA Technical Center

pilots participated in this phase of the test. All five flew the 23 flight profiles for each sensor height as shown in appendix C-3 and C-4.

The approach course/touchdown offset distance combinations were flown in a randomly selected order by each pilot. This procedure helped to control the influence of approach order on experiment results. All approaches were visual profiles to a landing decision point of 45 knots/100 feet AGL.

6.4 BASELINE DYNAMIC OVERPRESSURE TESTING.

After the approach/departure path test flights were completed, the S-76 helicopter was flown to verify results of the theoretical horizontal downwash pressure distribution studies reported in reference 1. Reference 1 developed analytical models of helicopter rotor effects on ambient horizontal and vertical wind velocity and atmospheric pressure.

The S-76 hovered at a horizontal distance of 75 feet from the AWOS, at rotor heights of 11, 22, and 100 feet AGL. Remote pressure sensor data were collected at 4, 5, and 6 feet AGL. The rotor heights represent the height of the rotor of an S-76 on the ground (11 feet), taxi altitude (22 feet) and out of ground effect hover altitude (100 feet). The hover times were recorded manually and the pressure data were recorded 10 times each second on magnetic tape cartridges using an Hewlett Packard (HP)-85 computer located at the site. A total of nine hover flights were completed.

7. DATA PROCESSING AND ANALYSIS.

Since it was assumed that the sensors most influenced by the rotor down wash would be the wind and temperature sensors, data analysis was performed to determine: (1) if, in the presence of a helicopter operating at a preselected offset distance and altitude, the height of the wind sensor had an effect on the wind direction and wind speed recorded by the equipment; and (2) if the height of the temperature sensor had an effect on the temperature readings in the presence of an operating helicopter.

The data were collected and recorded via a telemetry data relay system. The data were telemetered from the heliport to the VAX/VMS computer located in the Flight Operations Building. The data link alignment is presented in appendix B, figure B-4. Figure B-5 depicts the AWOS equipment layout in the Flight Operations Building.

Software was developed to select desired flight times from multiple data files and calculate changes in wind direction, wind speed, and temperature. Once data from all flights were compiled, statistical procedures were used to test helicopter effects on sensors.

Analysis of variance (ANOVA) procedures (see appendix G) were carried out to examine changes in wind direction, wind speed, and temperature. ANOVA is a method of dividing or partitioning total experimental variation into specific sources of variation. For our experimental design, these sources included approach angle, touchdown distance, and sensor height. The wind sensor height was the variable of primary concern for the analysis of change in wind direction and wind speed attributed to helicopter influences. Temperature sensor height was the primary concern for the analysis of change in temperature

reading. In addition, a questionnaire was developed to gather input from the pilots who participated in the testing. The responses were stored and analyzed using spread sheet software on a personal computer.

For the heliport maneuvering and extended ground run tests, data were collected via printout from the central processing unit (CPU) located in the Flight Operations Building. The recorded wind direction and speed data were analyzed manually due to the small amount of data. For the maneuvering test, the means of the changes in the wind direction and speed, in the presence of the helicopter, were computed for each touchdown/offset hover height combination. For the extended ground run test, the means were computed for each touchdown offset.

For the baseline dynamic overpressure test, the barometric pressure at the time of flight was obtained from magnetic tapes. A program was written for the VAX to compute pounds per square foot of pressure at a given rotor height, 4, 5, and 6 feet above the ground. The helicopter was offset horizontally (75 feet) from the barometric sensor. The calculations were based on the pressure distribution charts in reference 1. The values from the pressure distribution charts were converted from lbs/ft^2 to lbs/in^2, then normalized for sea level pressure by adding a constant of 14.718 lbs/in^2 to the resulting over pressure value. This result was compared to the pressure printed from the magnetic tape.

8. TEST RESULTS.

8.1 APPROACH/DEPARTURE PATH TEST.

8.1.1 Analysis of Sensor Height Effect On Wind Direction.

The overall effect of wind sensor height on the test results is shown in table 1. The results of the multiple factor ANOVA indicate that significantly different results were obtained for the two different wind sensor heights. Means and standard deviations of the changes in wind direction from one minute to the next for different wind sensor heights are found in table 2. Plots of the means, at each touchdown distance/sensor height combination, for each approach azimuth are provided in appendix D, figure D-1. Review of table 2 shows that for 12 of the 23 combinations tested, significantly larger wind direction changes resulted with the 15-foot wind sensor height than the 30-foot wind sensor height.

Table 2 also indicates that the approach azimuth or touchdown offset distance had no significant effect on the detected changes in wind direction.

Table 3 shows the mean change in wind direction from one minute to the next compiled by approach azimuth regardless of touchdown distance. Five of the six approach azimuths indicate that significantly larger changes in direction resulted with the 15-foot height when compared with the 30-foot height ($p \leq 0.05$). For the sixth angle, 84°, the change in wind direction was significantly larger at the 15-foot height when tested at the 90 percent confidence level. Appendix D, figure D-2, shows the plots of the mean changes in wind direction for each sensor height and approach azimuth combination.

TABLE 1. ANALYSIS OF VARIANCE TABLE FOR CHANGE IN WIND DIRECTION FROM ONE MINUTE TO THE NEXT

	df	SS	MS	CALCULATED F VALUE	CRITICAL F 95% LEVEL
MAIN EFFECTS					
APPROACH (ROW)	5	276.84	55.37	0.96	2.22
TOUCHDOWN (COL)	4	214.60	53.65	0.93	2.38
SENSOR HT (EFFECT)	1	5090.78	5090.78	87.98	3.85*
INTERACTIONS					
APPROACH BY TOUCHDOWN	13	552.29	42.48	0.76	1.73
APPROACH BY SENSOR HT	5	78.63	15.73	0.27	2.22
TOUCHDOWN BY SENSOR HT	4	61.40	15.35	0.27	2.38
APPRCH BY TCHDWN BY HT	13	1095.12	84.24	1.46	1.73
ERROR	834	48255.90	57.86		

*SIGNIFICANT F VALUE

KEY	
df	degrees of freedom
SS	sum of squares
MS	mean squared
F	F statistic

TABLE _. MEAN AND STANDARD DEVIATION OF CHANGES IN WIND DIRECTION IN DEGREES FROM ONE MINUTE TO THE NEXT DUE TO HELICOPTER PRESENCE

TOUCHDOWN DISTANCE		75		105		135		165		195	
SENSOR HEIGHT		15 FEET	30 FEET	15 FEET	30 FEET	15 FEET	30 FEET	15 FEET	30 FEET	15 FEET	30 FEET
354	MEAN	10.00	2.11*	8.57	5.24	6.47	3.50**	10.53	4.09*	8.33	3.18*
APA	STD DEV	9.49	5.35	9.10	5.12	7.86	4.89	10.26	5.03	8.57	4.77
324	MEAN	7.62	4.21	11.67	4.00*	9.41	3.00*	7.04	3.00*	9.38	4.09*
APA	STD DEV	8.89	5.07	10.98	5.03	10.88	4.70	5.88	4.70	9.29	5.03
24	MEAN	8.33	5.00**	11.11	3.81*	10.00	2.38*	6.47	3.89**	5.50	4.09
APA	STD DEV	7.18	5.13	10.79	5.90	10.69	4.36	4.93	6.08	8.87	5.03
54	MEAN	NA	NA	NA	NA	7.06	4.55	9.00	5.00**	15.00	5.00*
APA	STD DEV					8.49	5.10	10.21	5.15	11.80	5.13
84	MEAN	NA	NA	NA	NA	NA	NA	8.42	6.67	10.00	4.78*
APA	STD DEV							11.19	6.86	8.17	5.93
114	MEAN	NA	NA	NA	NA	7.00	4.50	11.00	2.63*	7.00	4.71
APA	STD DEV					10.31	5.10	13.34	4.52	9.23	5.15

* SIGNIFICANT DIFFERENCE BETWEEN MEAN AT WIND SENSOR HEIGHT OF 15 AND 30 FEET AT CONFIDENCE = 95%

** SIGNIFICANT DIFFERENCE BETWEEN MEAN AT WIND SENSOR HEIGHT OF 15 AND 30 FEET AT CONFIDENCE = 90%, BUT NOT 95%

NA COMBINATION NOT FLOWN

APA = APPROACH AZIMUTH

TABLE . MEAN AND STANDARD DEVIATION OF CHANGES IN WIND DIRECTION IN DEGREES FROM ONE MINUTE TO THE NEXT DUE TO HELICOPTER PRESENCE (APPROACH AZIMUTH ONLY)

APPROACH AZIMUTH (DEG)			SENSOR HEIGHT 15 FEET	30 FEET
	354	MEAN	8.85	3.65*
		STD DEV	9.05	5.04
	324	MEAN	8.99	3.66*
		STD DEV	9.30	4.84
	24	MEAN	8.17	3.82*
		STD DEV	8.91	5.27
	54	MEAN	10.00	4.83*
		STD DEV	10.39	5.04
	84	MEAN	9.21	5.61**
		STD DEV	9.69	6.34
	114	MEAN	8.33	3.93*
		STD DEV	11.07	4.93

* SIGNIFICANT DIFFERENCES BETWEEN MEAN AT 15 AND 30 FEET AT CONFIDENCE = 95%

** SIGNIFICANT DIFFERENCES BETWEEN MEAN AT 15 AND 30 FEET AT CONFIDENCE = 90%, BUT NOT 95%

An ANOVA was performed to examine wind sensor height effect on change in wind direction for five touchdown distances, regardless of approach azimuth. Again, the sensor height is significant (see table 4). Plots of the mean change in wind direction from one minute to the next for each sensor height/touchdown distance combination are found in appendix D, figure D-3.

Table 5 lists the mean changes in wind direction for touchdown distances, *regardless of approach azimuth. The 15-foot height produced significantly* higher changes in wind direction for all five distances ($p \leq 0.05$).

8.1.2 Analysis of Sensor Height Effect on Wind Speed.

The results of the ANOVA, table 6, indicate that the changes in wind speed computed from data with the sensor at 15 feet differed significantly from the changes computed with the sensor at 30 feet ($p \leq 0.05$). The results also indicate that touchdown distance interacts significantly with the sensor height.

Means and standard deviations of the changes in wind speed for both sensor heights are found in table 7. Plots of the data are provided in appendix D, figure D-4.

By examining table 7 it can be seen that 4 of the 23 approach azimuth/touchdown distance combinations show significantly higher mean changes in wind speed at the 15-foot sensor height ($p \leq 0.05$). Two of the combinations revealed significantly higher changes at the 15-foot sensor height with $p \leq 0.10$.

Examination of the mean changes in wind speed for touchdown offset distances, regardless of approach azimuth, reveal changes in wind speed at the 15-foot height for the 75 and 105-foot offset distances were significantly greater than the changes at the 30-foot height ($p \leq 0.05$). This result is presented in table 8. Plots of these means are found in appendix D, figure D-5.

An ANOVA was also performed to examine wind sensor height effect on wind speed changes for the six approach azimuths, regardless of touchdown distance. This ANOVA, table 9, indicates that sensor height is the only significant factor when the touchdown distance factor is ignored ($p \leq 0.05$). Table 10 gives the mean changes in wind speed for each approach azimuth, by sensor height combination. Appendix D, figure D-6, provides plots of these means.

8.1.3 Analysis of Sensor Height Effect on Temperature.

Appendix D, figure D-7, contains the plots of the mean changes in temperature, from one observation to the next, for each approach azimuth/touchdown distance combination at each temperature sensor height (5 and 10 feet). The results of the ANOVA, table 11, indicate that changes in temperature, computed from data collected with the sensor at 5 feet, do not differ significantly from the changes computed with the sensor at 10 feet ($p \leq 0.05$). Since there were no significant differences found by the ANOVA, further breakdown of the data by approach azimuth, regardless of touchdown distance, was not performed.

TABLE 4. ANALYSIS OF VARIANCE TABLE FOR CHANGE IN WIND DIRECTION FROM ONE MINUTE TO THE NEXT TOUCHDOWN DISTANCES ONLY

	df	SS	MS	CALCULATED F VALUE	CRITICAL F 95% LEVEL
TOUCHDOWN (ROW)	4	198.10	49.52	0.86	2.38
SENSOR HEIGHT (COL)	1	4768.20	4768.20	82.66	3.85*
TOUCHDOWN BY SENSOR HT	4	57.31	14.33	0.25	2.38
ERROR	870	50182.85	57.68		

* SIGNIFICANT F VALUE (SEE KEY IN TABLE 1)

TABLE 5. MEAN AND STANDARD DEVIATION OF CHANGES IN WIND DIRECTION IN DEGREES FROM ONE MINUTE TO THE NEXT DUE TO HELICOPTER PRESENCE

TOUCHDOWN DISTANCE (FEET)		SENSOR HEIGHT 15 FEET	SENSOR HEIGHT 30 FEET
75	MEAN	8.70	3.79*
	STD DEV	8.70	5.24
105	MEAN	10.35	4.35*
	STD DEV	10.17	5.32
135	MEAN	7.91	3.59*
	STD DEV	9.59	4.82
165	MEAN	8.84	4.17*
	STD DEV	9.84	5.46
195	MEAN	8.88	4.29*
	STD DEV	9.45	5.13

* SIGNIFICANT DIFFERENCES BETWEEN MEAN AT 15 AND 30 FEET AT 95%

TABLE 5. ANALYSIS OF VARIANCE TABLE FOR CHANGE IN WIND SPEED IN KNOTS FROM ONE MINUTE TO THE NEXT DUE TO HELICOPTER PRESENCE

	df	SS	MS	CALCULATED F VALUE	CRITICAL F 95% LEVEL
MAIN EFFECTS					
APPROACH (ROW)	5	6.57	1.31	1.34	2.22
TOUCHDOWN (COL)	4	9.83	2.46	2.51	2.38*
SENSOR HT (EFFECT)	1	1.42	1.42	14.50	3.85*
INTERACTIONS					
APPROACH BY TOUCHDOWN	13	11.96	0.92	0.94	1.73
APPROACH BY SENSOR HT	5	9.27	1.85	1.90	2.22
TOUCHDOWN BY SENSOR HT	4	9.38	2.35	2.40	2.38*
APPRCH BY TCHDWN BY HT	13	9.58	0.74	0.75	1.73
ERROR	861	8.42	0.98		

* SIGNIFICANT F VALUE (SEE KEY IN TABLE 1)

TABLE 7. MEAN AND STANDARD DEVIATION OF CHANGES IN WIND SPEED IN KNOTS

FROM ONE MINUTE TO THE NEXT DUE TO HELICOPTER PRESENCE

TOUCHDOWN DISTANCE		75		105		135		165		195	
SENSOR HEIGHT		15 FEET	30 FEET	15 FEET	30 FEET	15 FEET	30 FEET	15 FEET	30 FEET	15 FEET	30 FEET
354	MEAN	1.59	.95*	1.10	.76	1.37	1.15	.74	.86	1.22	1.00
APA	STD DEV	1.22	.91	.90	.89	1.21	1.04	.81	.77	.65	.98
324	MEAN	1.59	.84*	1.57	1.00**	1.30	1.00	1.16	1.0	.82	.64
APA	STD DEV	1.10	.83	1.50	.97	1.03	1.03	1.01	1.03	.81	.66
24	MEAN	1.69	1.20	1.58	.86*	1.53	1.19	1.63	1.11	1.15	.82**
APA	STD DEV	1.35	1.01	1.17	.65	1.42	0.75	1.42	.96	.75	.80
54	MEAN	NA	NA	NA	NA	1.21	1.14	1.0	1.33	1.07	.65
APA	STD DEV					.98	.94	.79	1.03	1.14	.49
84	MEAN	NA	NA	NA	NA	NA	NA	1.25	1.22	.95	1.39
APA	STD DEV							1.12	1.11	1.28	1.12
114	MEAN	NA	NA	NA	NA	1.15	1.1	1.24	.83*	.95	1.24
APA	STD DEV					.88	.91	.89	.83	.69	.75

* SIGNIFICANT DIFFERENCE BETWEEN MEAN AT WIND SENSOR HEIGHT OF 15 AND 30 FEET AT CONFIDENCE – 95%

** SIGNIFICANT DIFFERENCE BETWEEN MEAN AT WIND SENSOR HEIGHT OF 15 AND 30 FEET AT CONFIDENCE – 90%, BUT NOT 95%

NA COMBINATION NOT FLOWN

APA – APPROACH AZIMUTH

TABLE 8. MEAN AND STANDARD DEVIATION OF CHANGES IN WIND SPEED IN KNOTS FROM ONE MINUTE TO THE NEXT DUE TO HELICOPTER PRESENCE (TOUCHDOWN DISTANCE ONLY)

			SENSOR HEIGHT	
			15 FEET	30 FEET
TOUCHDOWN DISTANCE (FEET)	75	MEAN	1.62	1.00*
		STD DEV	1.19	0.92
	105	MEAN	1.41	0.87*
		STD DEV	1.22	0.84
	135	MEAN	1.31	1.12**
		STD DEV	1.09	0.92
	165	MEAN	1.17	1.02
		STD DEV	1.04	0.96
	195	MEAN	1.03	0.95
		STD DEV	0.90	0.87

* SIGNIFICANT DIFFERENCES BETWEEN MEAN AT 15 AND 30 FEET AT CONFIDENCE ≥ 95%

** SIGNIFICANT DIFFERENCES BETWEEN MEAN AT 15 AND 30 FEET AT CONFIDENCE ≥ 90%, BUT NOT 95%

TABLE 9. ANALYSIS OF VARIANCE TABLE FOR CHANGE IN WIND SPEED IN KNOTS FROM ONE MINUTE TO THE NEXT (APPROACH AZIMUTH ONLY)

	df	SS	MS	CALCULATED F VALUE	CRITICAL F 95%LEVEL
APPROACH (ROW)	5	6.12	1.23	1.25	2.22
SENSOR HEIGHT (COL)	1	7.29	7.29	7.42	3.85*
APPROACH BY SENSOR HT	5	9.76	1.95	1.99	2.22
ERROR	895	879.07	0.98		

* SIGNIFICANT F VALUE (SEE KEY IN TABLE 1)

TABLE 10. MEAN AND STANDARD DEVIATION OF CHANGES IN WIND SPEED IN KNOTS FROM ONE MINUTE TO THE NEXT DUE TO HELICOPTER PRESENCE (APPROACH AZIMUTH ONLY)

APPROACH AZIMUTH (DEG)		SENSOR HEIGHT 15 FEET	SENSOR HEIGHT 30 FEET
354	MEAN	1.21	.94*
	STD DEV	1.01	.9[illegible]
324	MEAN	1.31	.89*
	STD DEV	1.14	.90
24	MEAN	1.51	1.03*
	STD DEV	1.22	.84
54	MEAN	1.09	1.03
	STD DEV	.95	.88
84	MEAN	1.10	1.32
	STD DEV	1.19	1.11
114	MEAN	1.11	.98
	STD DEV	.82	.86

* SIGNIFICANT DIFFERENCES BETWEEN MEAN AT 15 AND 30 FEET AT CONFIDENCE = 95 %

TABLE 11. ANALYSIS OF VARIANCE TABLE FOR CHANGE IN TEMPERATURE FROM ONE MINUTE TO THE NEXT

	df	SS	MS	CALCULATED F VALUE	CRITICAL F 95% LEVEL
MAIN EFFECTS					
APPROACH (ROW)	5	0.50	0.10	1.84	2.22
TOUCHDOWN (COL)	4	0.44	0.11	2.03	2.38
SENSOR HT (EFFECT)	1	0.00	0.00	0.01	3.85
INTERACTIONS					
APPROACH BY TOUCHDOWN	13	0.64	0.05	0.02	1.73
APPROACH BY SENSOR HT	5	0.37	0.08	1.39	2.22
TOUCHDOWN BY SENSOR HT	4	0.33	0.08	1.54	2.38
APPRCH BY TCHDWN BY HT	13	1.12	0.09	1.60	1.73
ERROR	861	46.41	0.05		

(SEE KEY IN TABLE 1)

8.1.4 Questionnaire Analysis.

Each pilot was requested to complete a post-flight questionnaire regarding pilot background information, opinion of AWOS performance, and their recommendations for the use of AWOS at heliports. The questionnaire is shown in appendix E. The following is a summary of the responses to the questionnaires. Some questions required a rating from 1 (poor) to 5 (excellent).

For the testing with the wind sensor at 15 feet, four of the five pilots completed the questionnaire while all five responded when the sensor was at 30 feet.

8.1.4.1 Reception of Information.

Only two pilots had the opportunity to test the reception of the AWOS on the VHF radio at distances greater than 2 miles. They reported receiving the AWOS information at 40 or more nautical miles (nmi) from the heliport.

8.1.4.2 Accuracy of the AWOS.

The accuracy of the AWOS reports was rated above average by the subject pilots. Two pilots felt the accuracy was excellent at all sensor heights tested. One pilot rated the accuracy as fair, regardless of sensor height.

8.1.4.3 Overall System Evaluation.

For the overall system, the responses were similar for both the 15 and 30-foot tests. The system was rated above fair at 15 feet, and slightly higher at 30 feet. One pilot rated the overall system between fair and above fair for the 15-foot test, and higher for the 30-foot test, whereas, another rated it above fair for both tests. One pilot commented that there was a discrepancy between the reported Atlantic City Control Tower and AWOS altimeter settings, but this was not substantiated by the data.

8.1.4.4 Suitability.

Question four asked for a rating of the suitability of the AWOS for heliport operations. For the 15-foot test, all four pilots rated it between fair and excellent. When the tower was at 30 feet, two pilots rated the system excellent and three pilots rated it between fair and excellent. One pilot commented that to be excellent the system would have to be interactive, i.e., respond to pilot interrogation.

8.1.4.5 Location.

The question concerning location of the AWOS brought varied ratings. For the 15-foot sensor height, there were four different responses ranging from below fair to excellent. At 30 feet only one pilot was consistent with his rating from the 15-foot test. One upgraded his response from fair to above fair. Two lowered their rating one rank, and the fifth pilot felt the location was poor. Three of the pilots commented that the wind sensor was too close to the heliport, created an additional obstacle, and/or cluttered the landing area. It is noted that the siting conformed to visual approach clear zones in the Draft Heliport Design Guide for the 024°, 324°, and 354° approach courses.

8.1.4.6 Comparison of AWOS to Tower Ceiling and Visibility Information.

The pilots were also asked to compare AWOS ceiling and visibility information with the tower information. Of the four pilots responding to the question, two reported AWOS ceiling information as missing at times, and two said ceiling and visibility reported by AWOS agreed with the tower. One reported that AWOS visibility was 3 nmi less than the tower's, while one pilot indicated the visibility reported by both agreed. One pilot commented that the ceiling and visibility information from the AWOS seldom agreed with the tower's information. (Note: the visibility sensor is unable to provide actual distance information when the visibility exceeds 5 miles.)

8.1.4.7 Further Comments.

To the question, "What did you like best about the AWOS?", the pilots responded: altimeter and wind information (two pilots); essential information is provided; the report is "short and sweet"; and "It is just like the ATIS."

To the question, "What did you like least?", the responses were: "Missing ceiling information" (three pilots); "Inaccurate visibility" (two pilots); "Too close to the heliport" (three pilots); and "The 30-foot tower created an obstacle."

All five pilots responded that there was no increase in workload with the tower at 15 feet. One said there was an increase when the tower was at 30 feet due to the additional obstacle clearance requirements. Another pilot said the radio transmissions were too noisy. This problem was found to be with the GRT-21 transmitter and was resolved by adjusting the transmitter.

Responses to what additional information might be needed, one pilot indicated that local notice to airmen (NOTAMS) concerning heliport changes and obstacles, as well as approach course information, would be useful. It is anticipated that the inclusion of the additional information will clutter the frequency and not permit the equipment to work in the manner that it was designed.

As to overall comments, three pilots felt the AWOS provided useful real time information. Comments were also received such as "Wind information was a big help and the 30-foot sensor height was less effected by rotor wash." One pilot said, "The anemometer tower should be as low as possible." He suggested for obstruction clearance and physical safety, the AWOS be located as far as possible from the takeoff and landing area without degrading system performance.

8.2 HELIPORT MANEUVERING TESTS.

Even though there were two large wind direction changes (80° and 50°) of the 10-foot maneuvering height for the 75 and 105 feet touchdown offset distances, the overall effect of the aircraft's 3-minute maneuvers was determined not to be significant.

When the aircraft maneuvering height was 5 feet above the heliport, the mean changes in wind direction were 10°, 10°, and 2.5°, respectively, for the 75, 105, and 195-foot touchdown offset distances. The mean changes in wind speed for these distances were 1.3, 1.5, and 0.5 knots.

For selected touchdown offset distances with the helicopter maneuvering at 10 feet, the mean changes in wind direction were 37.5° (75 feet), 22.5° (105 feet), and 2.5° (195-feet). Thus, at the two closest positions, the mean changes in wind direction increased. At the 195-foot touchdown offset, there was no increase. The mean changes in speed stayed about the same; 1, 2.5, and 1.5 knots for the 75, 105, and 195-foot offsets.

Mean changes in wind direction, at the two closest positions, for 20-foot maneuvering height were lower than those at the 10-foot maneuvering height. At the 195-foot touchdown offset, the mean change was larger for the 20-foot maneuvering height. The mean changes in wind direction at the 75, 105, and 195-foot distances were 7.5°, 12.5°, and 10° with the mean changes in wind speed similar to the means at the other two heights at 1.5 and 1.5 and 1.75 knots.

The mean changes in wind direction at 25-foot height were 10°, 15°, and 10° for the respective three distances with mean changes in wind speed of 2.25, 1.25, and 0.75 knots. These means correspond closely to the mean changes found at the 20-foot maneuvering height.

8.3 EXTENDED GROUND RUN TESTS.

Even with two large changes (40° and 50°) in wind direction at the 105-foot touchdown offset distance and two (40° and 60°) at the 135-foot offset distance, the overall means of the change in wind direction and wind speed are not large enough to indicate any long term hovering effects on AWOS performance. The means of the changes in direction range from 8.57° at the 165-foot offset to 17.14° at 135-foot. The means of changes in speed range from 0.89 knots at 75 feet to 1.56 knots at 195 feet.

The 105-foot data from the second test compare closely to the original 105-foot test data. The original mean for direction and speed were 16° and 1.4 knots, while the mean for the repeat test were 14.29° and 1.93 knots.

8.4 BASELINE DYNAMIC OVERPRESSURE TEST.

The printout of barometric pressures from the magnetic tape corresponded to the pressures computed using the charts from reference 1. At the sensor heights of 5 and 6 feet for rotor heights of 11, 22, and 110 feet the pressure readings were either 14.778 or 14.811 pounds per square inch (PSI). With the sensor height of 4 feet the recorded pressure readings ranged between 14.65 and 14.811 PSI. The calculated pressures for all three sensor heights and all three rotor heights ranged from 14.733364 to 14.75857 PSI. This compares favorably with the figures recorded from the equipment placed at the AWOS site. Thus, the pressures determined from the charts in reference 1, which were developed from static tests, were verified by actual hovering tests.

9. WEATHER RELATED OBSERVATION.

During the period of the AWOS evaluation, the opportunity arose to evaluate the equipment during times of varied environmental effects. The following is an example of AWOS behavior during these occurrences.

9.1 WET CONDITIONS (AUGUST 18-21, 1985).

During these 4 days, a total of 1.64 inches of rain fell at the heliport, with daily amounts of 0.82, 0.27, 0.43, and 0.12 inches. Only on August 19 did the AWOS show any precipitation, and its 0.28-inch measurement compared favorably to the National Weather Service measurement of 0.27 inches.

9.2 HURRICANE GLORIA (SEPTEMBER 27, 1985).

At 7:00 a.m. on September 27, 1985, the electric power at the airport was shut down. Only altimeter readings were recorded during the hurricane because the sensor, located in the CPU rack in the Data Systems Lab, was operational. The AWOS performance included an altimeter low of 28.71 inches of mercury (Hg). which matched the National Weather Service's low reading. Both readings were obtained at approximately the same time. When power was restored at 3:00 p.m.; the AWOS functioned properly. During this time the equipment was exposed to wind speeds exceeding 70 knots. A physical inspection of the equipment showed no sign of damage.

9.3 DRY CONDITIONS (OCTOBER 6-14, 1985).

Many dry periods occurred during 1985. During a 9-day period in early October, the AWOS performance was not effected.

9.4 SUSTAINED HIGH WINDS (NOVEMBER 1-4, 1985).

During this 4-day period, average wind speed ranged from 14.6 to 18.3 knots with gusts measured up to 26 knots. The AWOS showed no detrimental effects. The AWOS measurements were confirmed by those of the National Weather Service. All other system functions remained constant.

9.5 SNOW (DECEMBER 20, 1985).

The first major snow fall of the winter of 1985 delivered 4.2 inches. AWOS did not detect that precipitation because the heater on the funnel of the rain gauge was not operational. However, other sensor information compared favorably with official weather observations.

10. CONCLUSIONS.

The Automated Weather Observing System (AWOS) equipment suite is operationally suitable for heliport use. The equipment does not require a large piece of real estate for installation. This equipment can be installed in an area less than 40 square feet. The anemometer, the sensor most sensitive to rotor downwash, can be installed as close to the center of the landing pad as 75 feet when sited 30 feet above the landing area without being significantly affected by downwash. Subsequent testing has indicated that the equipment, with the anemometer as low as 20 feet, can be installed 75 feet from the center of the landing pad without any detectable effect on AWOS performance.

The dimensions noted throughout this report are based solely on sensor performance. It is acknowledged that there are or may be more restrictive requirements for the installation of this equipment at a heliport such as TERPS obstruction criteria. Therefore, a thorough obstacle clearance evaluation in conjunction with a site survey should be conducted prior to the installation of this equipment.

10.1 SITING.

a. AWOS equipment can be installed in a limited amount of real estate as dictated by siting restrictions, criteria of the Heliport Design Guide (Draft), AC 150/5220-16, and manufacturer's recommendations.

b. The meteorological tower containing the anemometer must be installed to meet obstruction clearance requirements of Terminal Instrument Procedures (TERPS), criteria of AC 150/5220-16, and the Heliport Design Guide (Draft). It should be noted that the anemometer can be sited remotely atop existing structure.

c. Data lines should be hard wired. The telemetry data link performed flawlessly, however, it is not recommended because of possible radio frequency (RF) interference and frequency allocation problems. If one is required, then careful selection of frequency and antenna sites are necessary.

10.2 OPERATIONAL SUITABILITY.

a. The AWOS is recommended for heliport installation. The equipment provides the user with up to date pertinent weather information in a timely manner.

b. Sensor activity is stable under most conditions when siting places the sensors outside the area of rotor influence.

c. The synthesized voice is understandable.

d. Due to real estate requirements, a forward scatter visibility sensor is more suitable than the backscatter visibility sensor for heliport installations. Forward scatter visibility sensor requires approximately 1 meter clearance, while a backscatter visibility sensor requires approximately 300 meters clearance in a northerly direction.

e. Based on the results of all tests, the AWOS equipment can be installed as close to the center of the takeoff and landing area as 75 feet.

f. Based on the results of all tests, the anemometer can be installed anywhere between 20 and 30 feet above the takeoff and landing area without influencing sensor performance.

g. The central processing unit rack requires a cooling unit (fan). Without it, it generates excessive heat whch may be detrimental to equipment life.

h. A fault in the interface (reverse S-12 card) between the ASEA ceilometer and the junction box was discovered. No pattern has been defected in the occurrence of intermittent ceilometer failure and recovery.

10.3 MAINTENANCE REQUIREMENTS.

Certain maintenance activities in addition to the manufacturer's prescribed tasks should be required for systems installed at heliports. These additional tasks include:

a. More frequent (monthly) changing of air filters due to increased dust and debris kicked up by rotorwash.

b. Remove outer cover and clean tipping buckets of accumulated debris (biweekly).

c. Check interior of sensors' outer housings for debris (monthly).

d. Add to the frequency of inspection of lightning protection devices the statement "immediately after lightning activity" (see appendix F).

REFERENCES

1. Schwartz, C.W., Witczak, M.H. and Leahy, R.B., Structural Design Guidelines For Heliports, DOT/FAA/PM-84/23, October 1984.

2. Heliport Design Guide, Draft FAA Advisory Circular AC 150/5390-xx, April 1986.

3. Johnson, Norman L. and Leone, Fred C., Statistics and Experimental Design in Engineering and the Physical Sciences, Vol 2, John Wiley and Sons, Inc., N.Y; 1964.

4. Meyers, Jerome L., Fundamentals of Experimental Design, Allyn and Bacon, Inc., Boston, 1972.

5. Automated Weather Observing Systems (AWOS) for Non-Federal Applications, FAA Advisory Circular AC 150/5220-16, April 11, 1986.

APPENDIX A
DESCRIPTION OF EQUIPMENT AND ALGORITHM

AWOS EQUIPMENT AND DESCRIPTION

1. Ceilometer (ASEA Electronics) - Continuously measures cloud height above the ground by means of timed reflections of laser pulses. Reports two different cloud bases up to 3,000 meters.

2. Skyvane Wind Sensor (WeatherMeasure) - Measures wind speed by means of a direct current (dc) tachometer connected to a propeller and wind direction by means of a potentiometer which varies output voltage with sensor direction. Measures wind speed from 2 to 200 knots and wind direction from 0° to 360°.

3. Motor Aspirated Radiation Shield (WeatherMeasure) - Provides mounting for dew point and temperature probes while shielding the probes from solar radiation and precipitation.

4. Thermistor Temperature Probe (WeatherMeasure) - Uses a precision three-element thermistor mounted in a stainless steel housing approximately 6 inches long. A slight change in temperature causes a rapid large change in the resistance of the thermistor. The three-element thermistor, in conjunction with its resistor network, has a linearity of 0.1° C over the range of -50° to +50° C.

5. Dew Point Thermistor Temperature Probe (WeatherMeasure) - Uses a bifilar wound heating element over a cavity encasing a precision three-element thermistor temperature sensor. The bifilar heater is wound over a fiberglass cloth treated with a lithium chloride salt solution. The salt becomes electrically conductive by absorbing moisture from the atmosphere. The electrical current heats the element to an equilibrium temperature condition as a function of the moisture content of the air. The temperature is measured by the thermistor network and translated to dew point temperature.

6. Tipping Bucket Rain Gauge (WeatherMeasure) - Uses a dual tipping bucket configuration to measure precipitation. Each bucket can hold the equivalent of 0.00394 inches of rain. As one bucket fills, it tips and makes contact with a mercury-wetted reed switch which increments the event counter. As the bucket tips, it also moves the other bucket under the collection funnel to provide continuous measurement. Accumulated water is emptied into a drain tube in the bottom of the sensor housing.

7. Wind Screen (WeatherMeasure) - Used to obtain improved accuracy of precipitation measurements. The rain screen consists of 32 free swinging tapered leaves on a 48-inch diameter metal ring mounted on four 24-inch legs. The leaves act as wind dampeners to prevent precipitation loss to the rain gauge due to the effects of wind and turbulence.

8. Backscatter Visibility Sensor (WeatherMeasure) - Used to measure horizontal visibiity from 0.1 to 5+ miles. The sensor transmits a precisely focused ON-OFF modulated light beam on a horizontal path. The light is scattered by airborne dust, fog, and smoke particles. Some of the light is reflected back to the sensor receiver where the intensity is measured. The received light intensity is compared to a table which correlates the density of floating particles to the transmission of light in the atmosphere.

9. Barometric Pressure Sensors (WeatherMeasure) - Uses a variable capacitance ceramic element. The symmetrical ceramic capsule deforms proportionally to the barometric pressure. This element is enclosed in a reference space and sealed under high vacuum. The range of the sensor is 600 to 1100 millibar $\pm$0.3 millibar. High level output is 0 to 5 volts direct current (dc).

10. Day/Night Detector (WeatherMeasure) - Designed for use with the Backscatter Visibiity Sensor to switch algorithms for computing horizontal visibility depending on ambient light conditions. Nighttime activation occurs when ambient light intensity falls below 1 - 5 footcandles. Daytime activation occurs when ambient conditions are above 3 - 15 footcandles. A lexan photo detector acts as a switch to control primary alternating current (ac) power to a step-down transformer whose output is either 0 volts for daytime or 5 volts for nighttime.

11. Remote Junction Boxes (WeatherMeasure) - Used for remote signal conditioning and preprocessing of sensor data. There are two boxes used in the Technical Center installation, a meteorological junction box and a visibility junction box. Each box contains an input power strip, signal and communications lightning protection, an insulation and heater assembly, and a signal conditioning module file. Also included in each box is a modular power supply, a remote data processor, and a 202-type communications modem. The meteorological junction box contains signal conditioning modules for wind speed, wind direction, temperature, dew point temperature, and precipitation. The input power strip provides power for all sensors, the signal conditioning module file, and the heater assembly. The visibility junction box contains signal conditioning modules for the Day/Night Detector, ASEA ceilometer, and the Backscatter Visibility Sensor. The input power strip provides power for the Day/Night Detector, signal conditioning module file, and the heater assembly.

12. Central Processing Unit Rack (WeatherMeasure) - Designed for monitoring, processing, and reporting data and the control of various functions to fulfill applications in meteorology and airport monitoring systems. The M733 microcomputer controls the acquisition of data from the signal conditioning equipment via radio telemetry equipment, performs virtually any mathematical functions relating to statistical analysis, correction for sensor non-linearities and drifts, checking limits and signal status flags, and formatting reports summaries for output to cassette tape, terminals (hard-copy, and cathode ray tube (CRT), and other peripherals such as the voice synthesizer, VHF radio, and fixed disc storage on the VAX 11/750.

The rack contains a signal conditioning module file, a central processing unit module file, a voice synthesizer, a discrete VHF radio transmitter, a VHF data telemetry transceiver, a cassette tape recorder, two barometric pressure transducers, and a cooling unit.

13. Data Telemetry System (WeatherMeasure) - This system consists of two low-power (1-2 watt) VHF transceivers, a radio junction box, and two heavy duty, high gain, directional antennas. One of the transceivers is located in the central processing unit rack and the other transceiver is located at the remote sensor site in the radio junction box. The antennas are located on the roof of the hangar and at the remote sensor site. The remote sensor site is located approximately 3/4 mile line-of-sight from the hangar.

14. CRT (TELEVIDEO) and Line Printer Terminals (Digital Equipment Corporation) - The CRT terminal is used as a remote display terminal for AWOS data. The information is updated each minute. The dot-matrix printer terminal is used for interaction with the central processor rack and hard-copy output of AWOS information. The hard-copy output interval is selected by two switch settings inside the CPU module file.

15. MW-33 Tower (TRI-EX) - This is a galvanized, tubular steel, hinged, telescoping tower. It can be extended from 11.5 to 33 feet by means of a 12-volt dc winch attached to the lowest section. Mounted on the tower are the Skyvane wind sensor, Day/Night Detector, motor aspirated radiation shield with temperature and dew point temperature probes, obstruction light, and lightning rod.

AWOS SENSOR DATA TIMING ALGORITHM

1. Wind Speed and Direction - Sample the sensors once every second. Each minute a running 2-minute average is calculated.

2. Wind Gusts - The 5-second average wind speed is updated each second. Each minute, store the highest 5-second average. Compare the current 2-minute average speed to the highest 5-second average for that minute. If the 2-minute average equals or exceeds 9 knots, and the difference between the 5-second average and the 2-minute average equals or exceeds 5 knots, store that 5-second average as gust. Compares the current 2-minute average and the highest gust stored during the last 10 minutes, and if this gust is at least 3 knots higher than the 2-minute average, it adds this gust to the wind observation. Include the wind gust in the observation for 10 minutes unless the gust falls within 3 knots of the current 2-minute average.

3. Temperature - Sample the sensor once every minute. If the temperature change within the last minute is less than 6°, calculate a running 5-minute average.

4. Dew Point - Sample the sensor once each minute. If dew point is 1° or 2° above temperature, dew point equals temperature. If the dew point change within the last minute is less than 6°, calculate a running 5-minute average.

5. Barometric Pressure - Read the two sensors every 10 seconds. Compute the 1-minute average for each sensor and output the lower of the two pressures as the current pressure.

6. Cloud Height - Sample the sensor once every 30 seconds. If less than 30 minutes of data are available, report ceiling missing for 10 minutes. Then an estimated ceiling is reported until 30 minutes of data has been collected.

7. Visibility - The central processor samples the sensor once each minute. The reported visibility is calculated from a 1-minute average of 30-second samples. If less than 10 minutes of data are available, average the available data and output the estimated visibility; otherwise, output the computed visibility.

8. Day/Night Detector - The sensor has a programmable time delay before switching. The recommended delay for airports is between 3 and 5 minutes.

9. Precipitation - Sample the sensor once each minute for an indication of precipitation. Record a count if one tip has occurred. If a second tip occurs within 10 minutes, report precipitation. Precipitation ends when no tips are recorded in a 10-minute period. The cumulative precipitation sensor is sampled once each minute. These are stored for cumulative 6 and 24-hour reports.

APPENDIX B

ILLUSTRATION OF AWOS SITE AND EQUIPMENT

Figure		Page
B-1	AWOS Heliport Installation	B-1
B-2	AWOS Site	B-2
B-3	AWOS Pads	B-3
B-4	View of Data Lab from AWOS Site	B-4
B-5	Central Processing Unit, Printer and Display	B-5

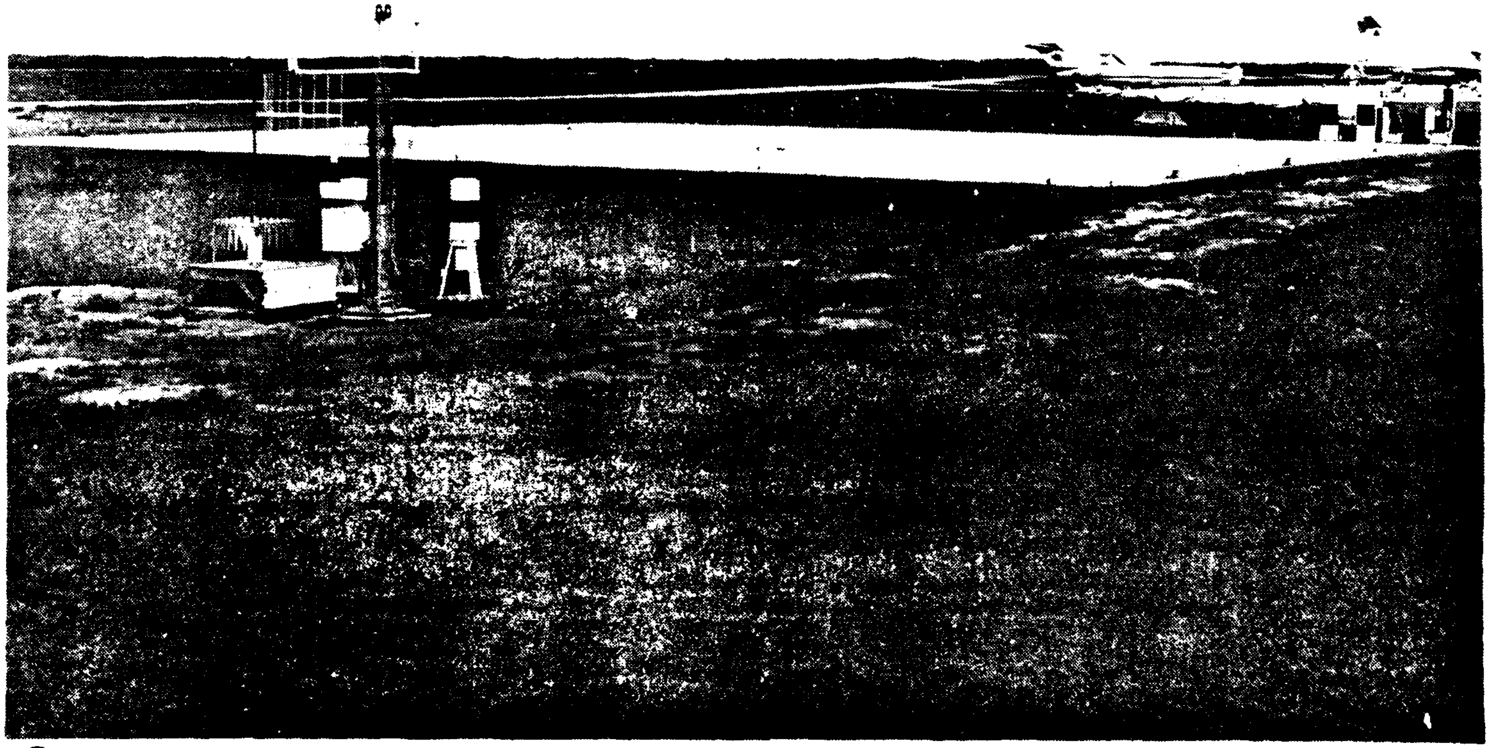

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FIGURE B-1. AWOS HELIPORT INSTALLATION

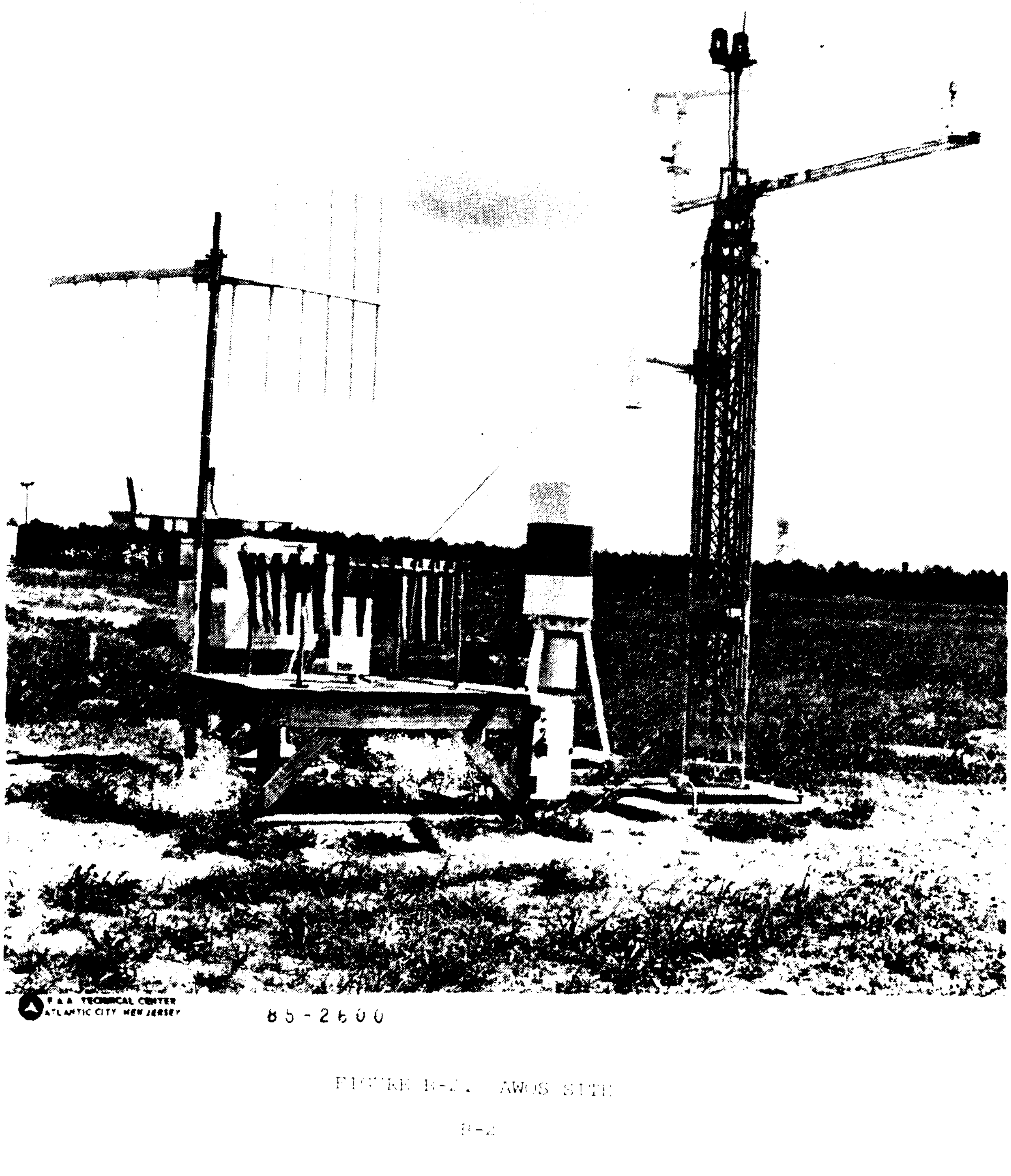
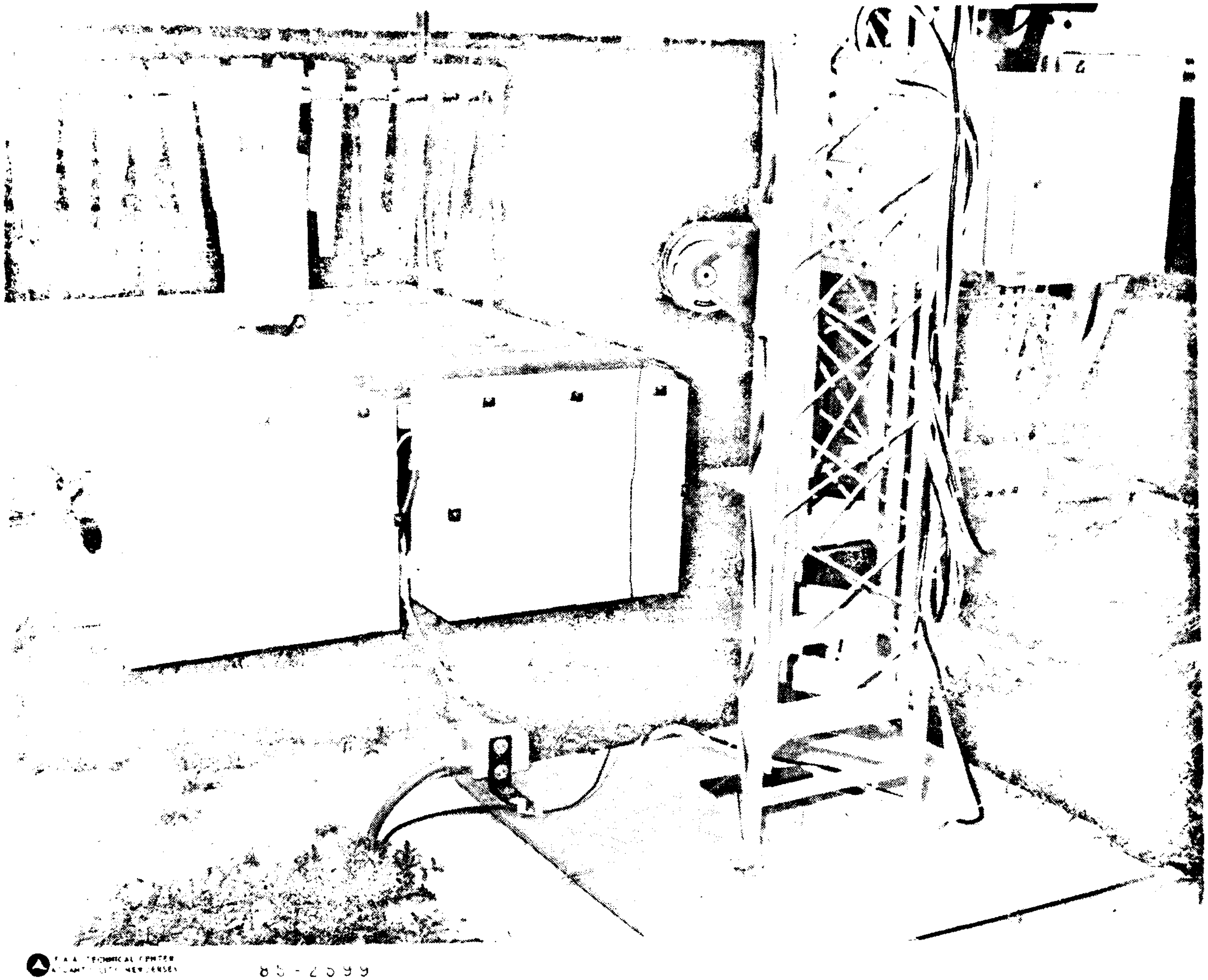


FIGURE B-2. AWOS SITE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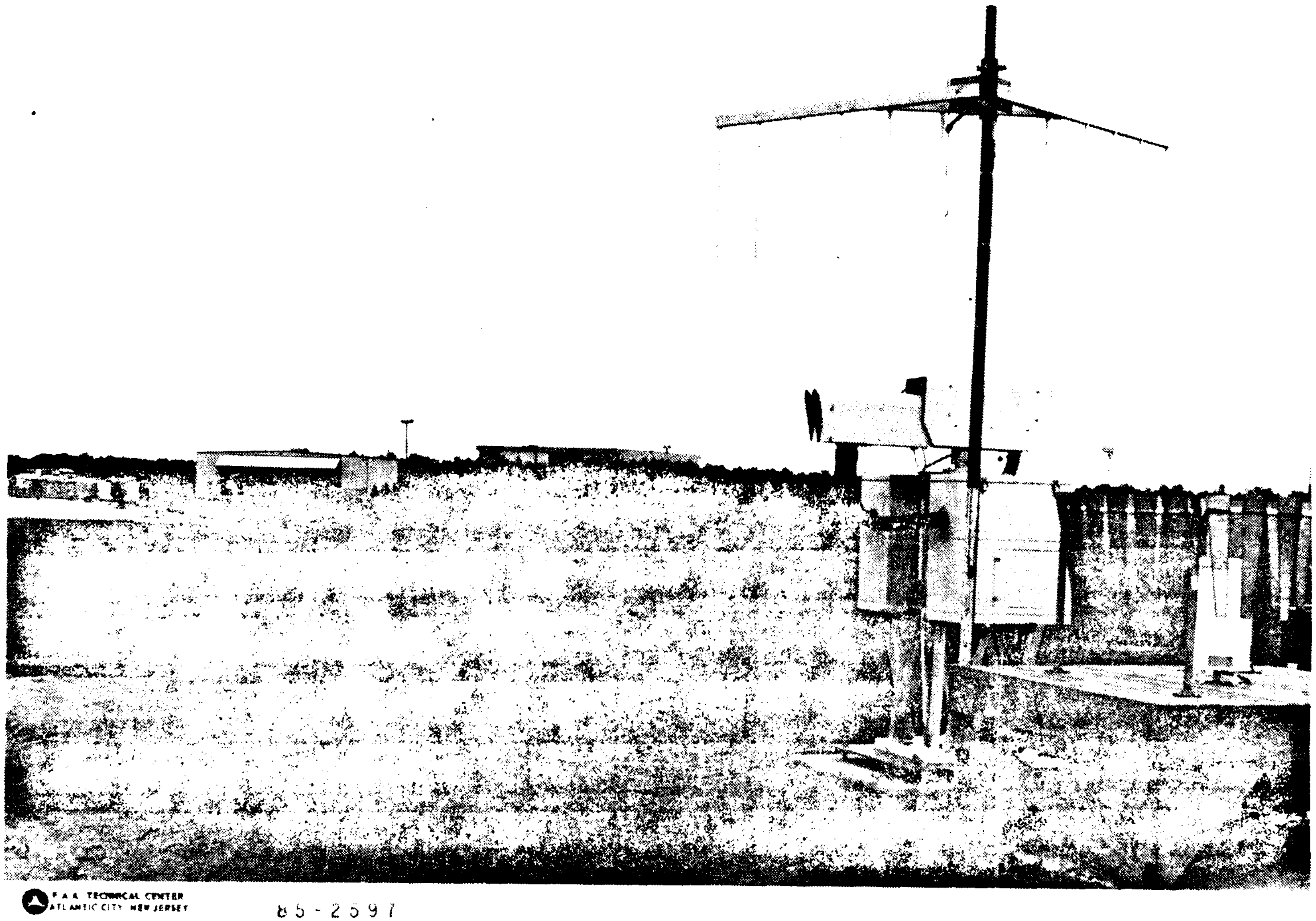
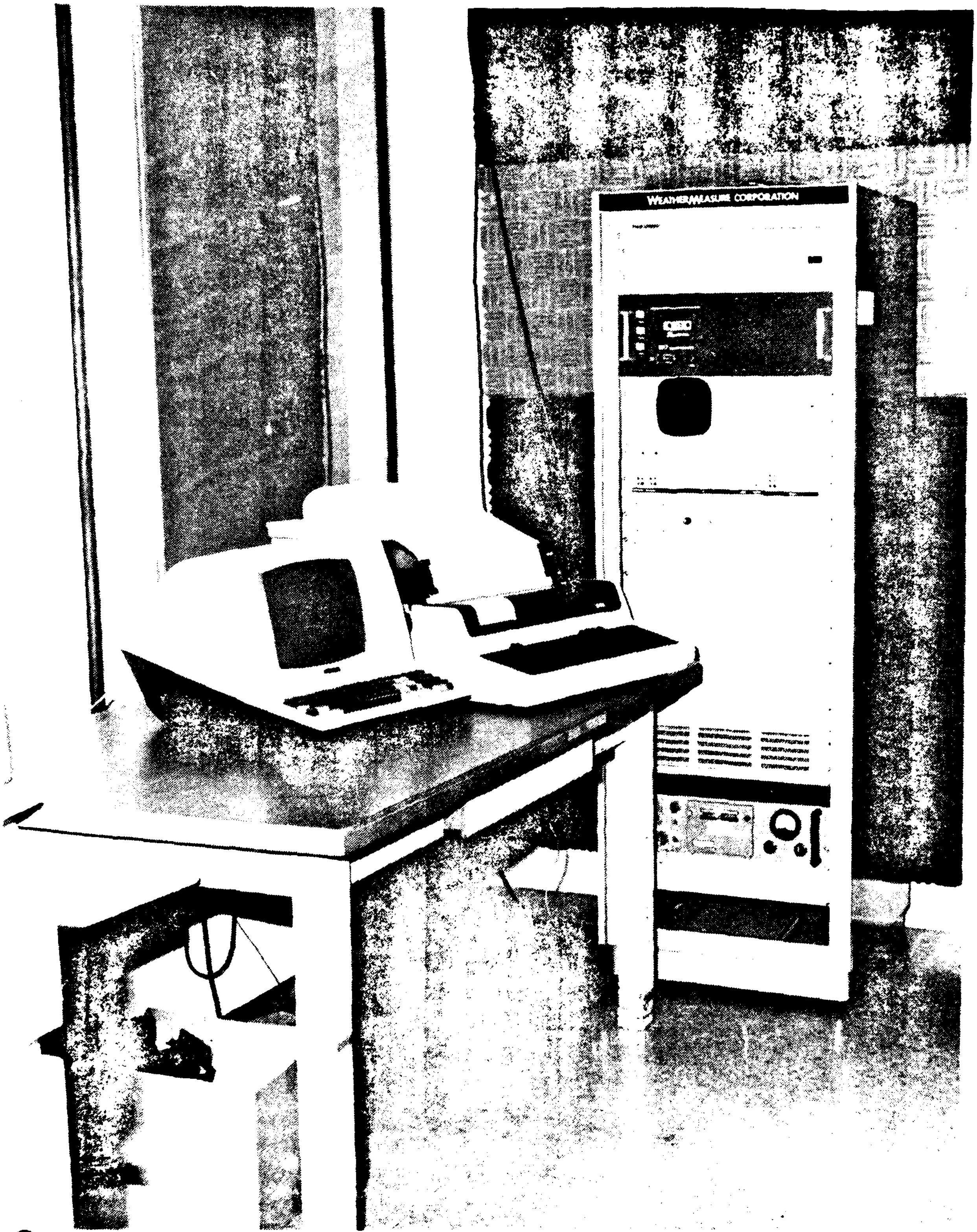


FIGURE B-4. VIEW OF DATA LAB FROM AWOS SITE



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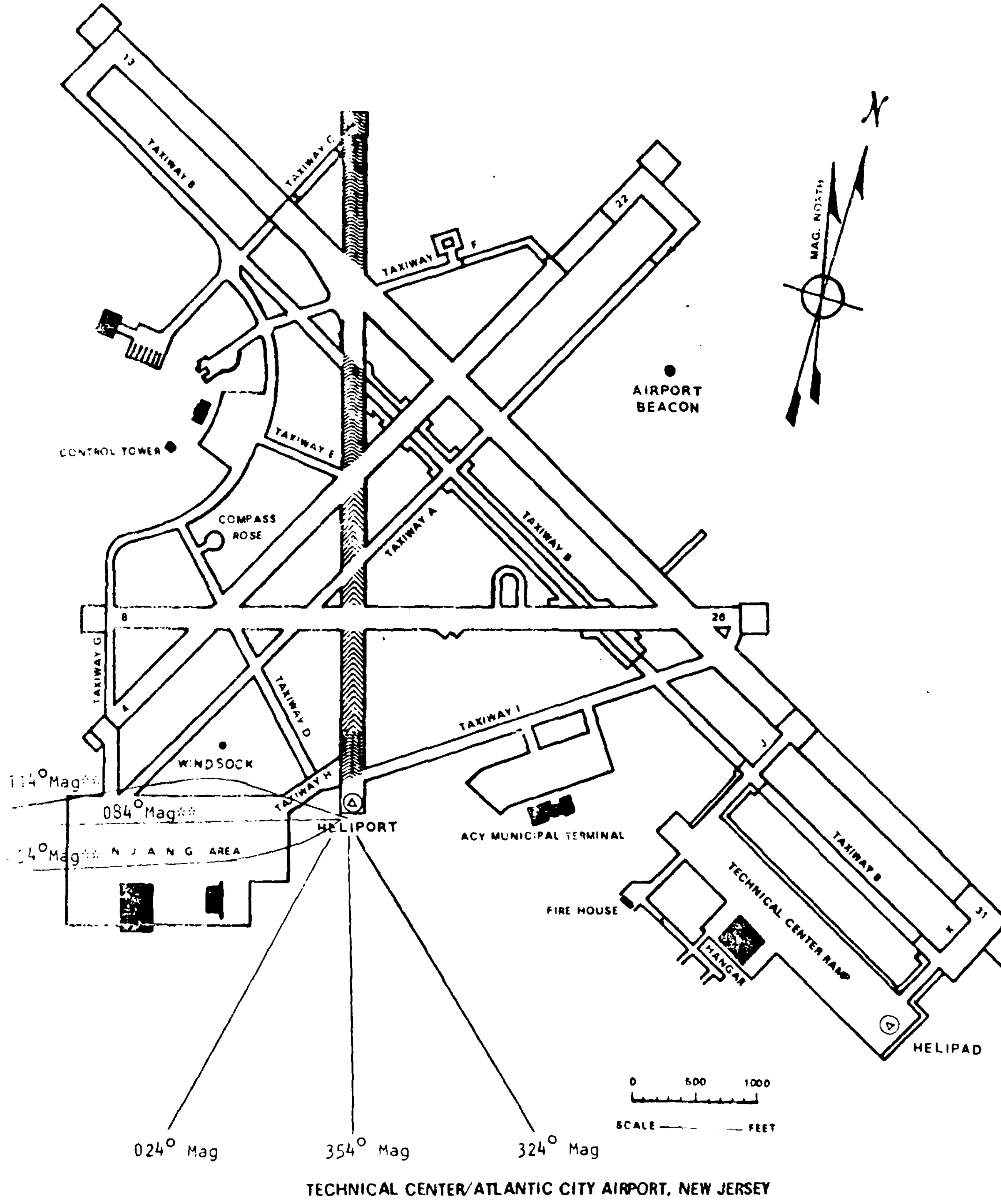
APPENDIX C
TEST FLIGHT EXPERIMENTAL DESIGN

APPENDIX C
TEST FLIGHT EXPERIMENTAL DESIGN

Figure		Page



** DO NOT OVER FLY ANY MEN? EQUIPMENT OR AIRCRAFT.

FIGURE C-1. AWOS TEST APPROACH PATHS

ASSIGNED COLORS FOR MARKERS

Baseline Markers:

1.	S-76	75 Feet	Yellow
2.	UH-1	82 Feet	Orange

Touchdown Offset Markers

1.	75 Feet	Yellow
2.	105 Feet	Yellow/Orange
3.	135 Feet	Orange
4.	165 Feet	Gray/Orange
5.	195 Feet	Gray/Yellow

PROFILES FOR AWOS RUNS 1 THROUGH 23

Wind Sensor Height: 30 Feet

Temperature Sensor Height: 10 Feet

Run Number	Approach Course	Touchdown Offset
1	354	75
2	354	105
3	354	135
4	354	165
5	354	195
6	324	75
7	324	105
8	324	135
9	324	165
10	324	195
11	24	75
12	24	105
13	24	135
14	24	165
15	24	195
16	54	135
17	54	165
18	54	195
19	84	165
20	84	195
21	114	135
22	114	165
23	114	195

PROFILES FOR AWOS RUNS 24 THROUGH 46

Wind Sensor Height: 15 Feet

Temperature Sensor Height: 5 Feet

Run Number	Approach Course	Touchdown Offset
24	354	75
25	354	105
26	354	135
27	354	165
28	354	195
29	324	75
30	324	105
31	324	135
32	324	165
33	324	195
34	24	75
35	24	105
36	24	135
37	24	165
38	24	195
39	54	135
40	54	165
41	54	195
42	84	165
43	84	195
44	114	135
45	114	165
46	114	195

BASELINE DATA FLIGHTS FOR THE S-76

Hovering Distance of 75 Feet from the Sensor

Sensor Height	Rotor Height
4.0 ft	11 ft (on ground)
4.0 ft	22 ft (ground effect)
4.0 ft	110 ft (out of ground effect)
5.0 ft	11 ft (on ground)
5.0 ft	22 ft (ground effect)
5.0 ft	110 ft (out of ground effect)
6.0 ft	11 ft (on ground)
6.0 ft	22 ft (ground effect)
6.0 ft	110 ft (out of ground effect)

APPENDIX D

TEST RESULTS

APPENDIX D
TEST RESULTS

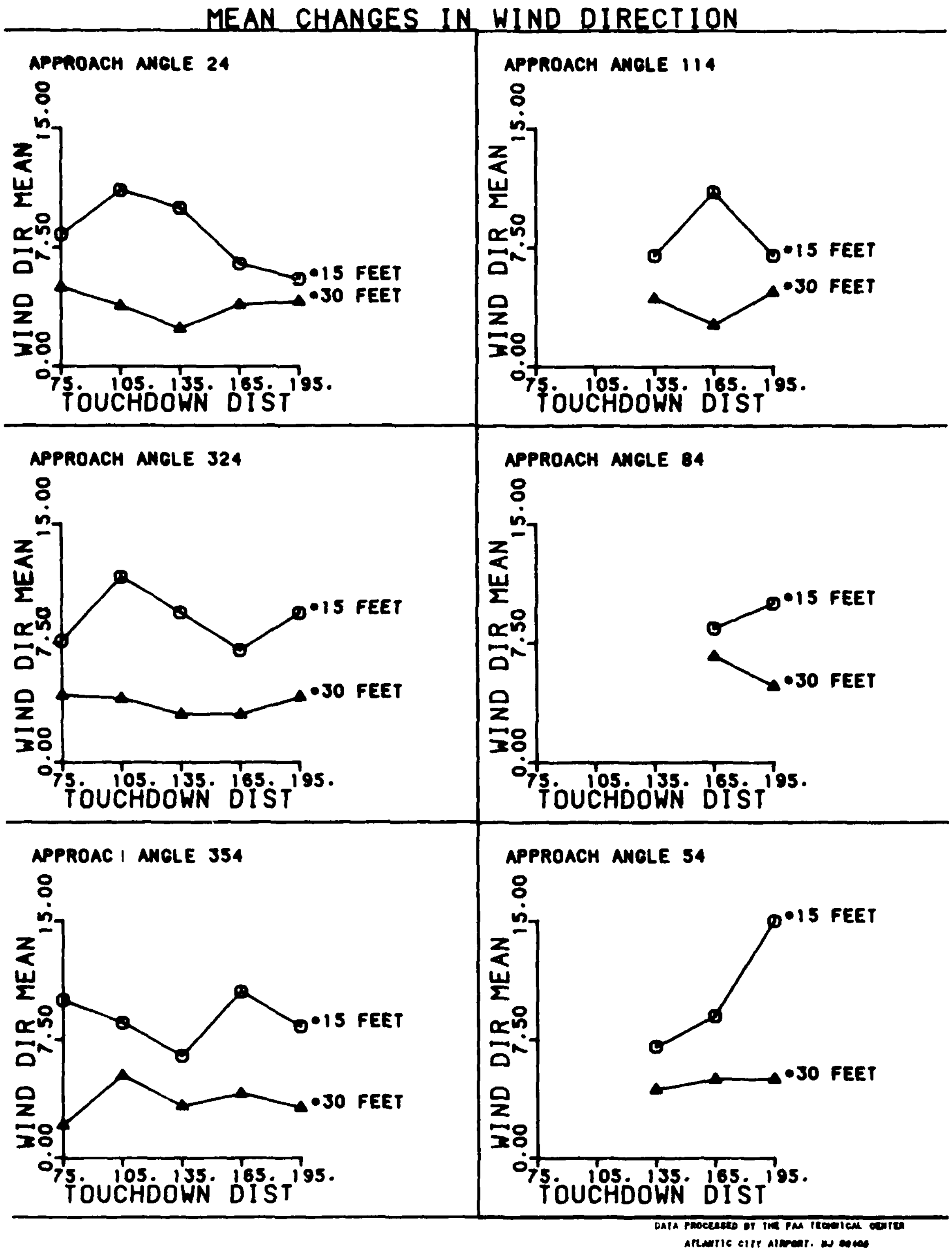


FIGURE D-1. MEAN CHANGES IN WIND DIRECTION TOUCHDOWN DISTANCE AND APPROACH AZIMUTH

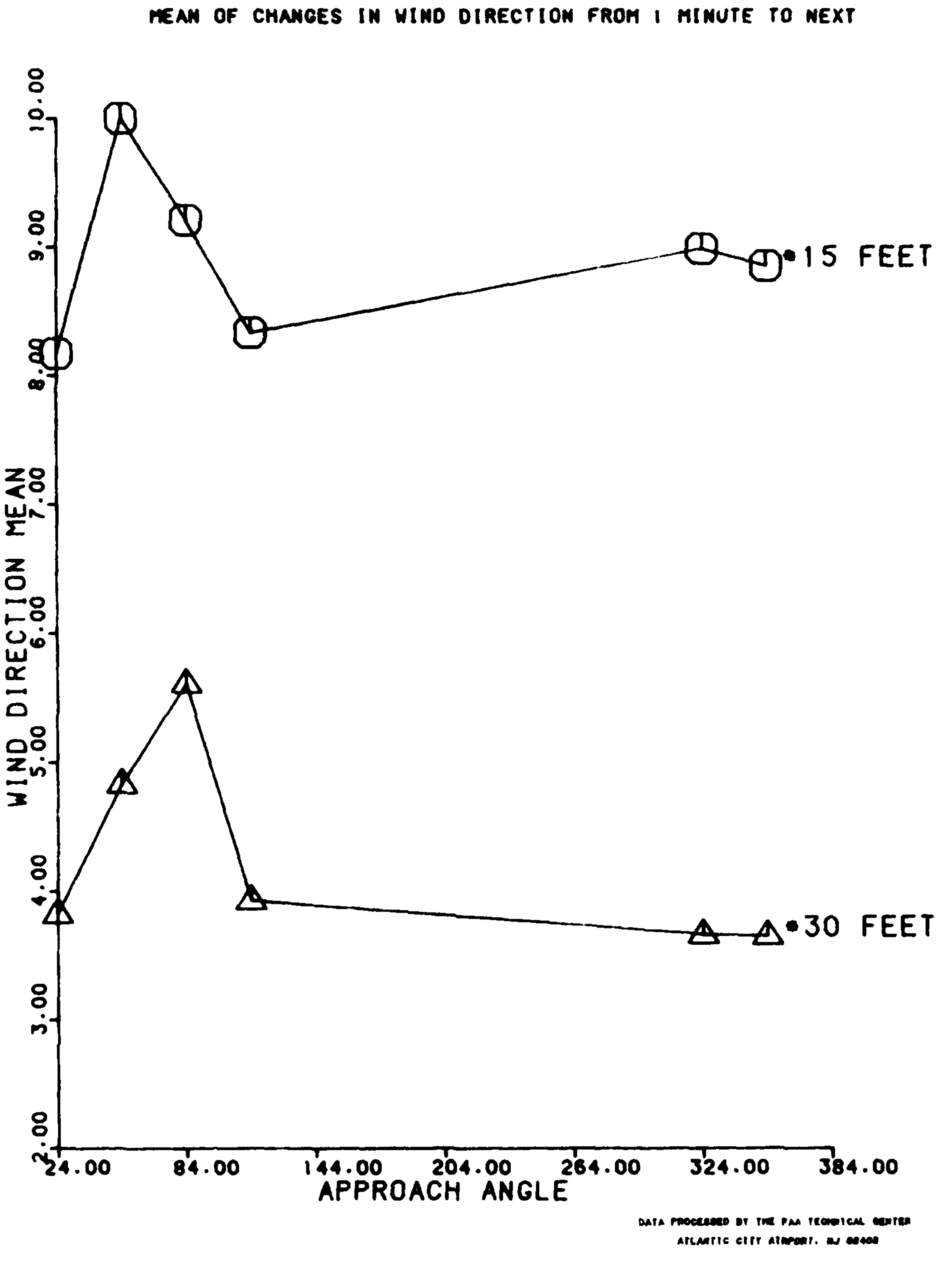


FIGURE D-2. MEAN CHANGES IN WIND DIRECTION FROM ONE MINUTE TO NEXT APPROACH AZIMUTH ONLY

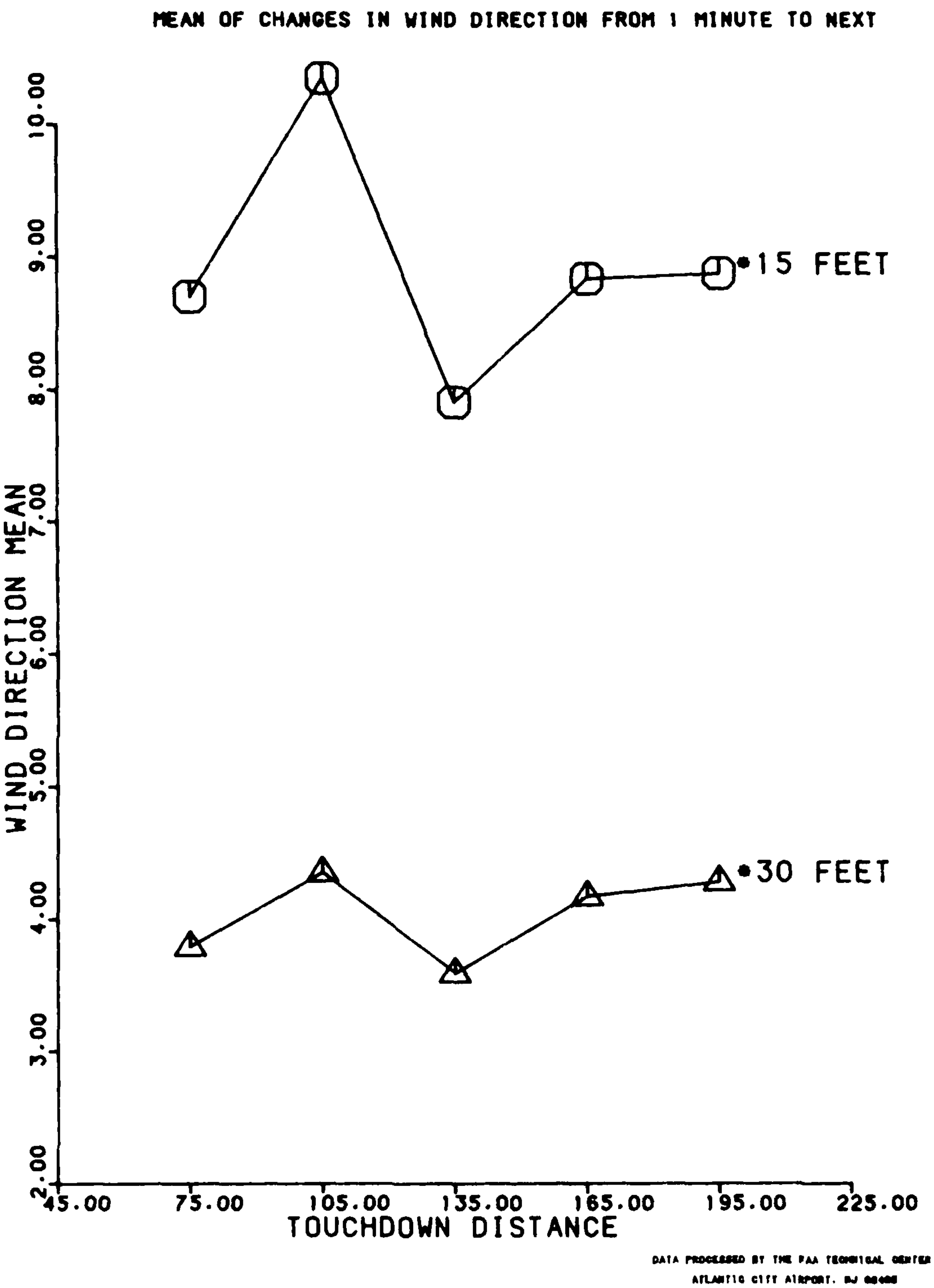


FIGURE D-3. MEAN CHANGES IN WIND DIRECTION TOUCHDOWN DISTANCE ONLY

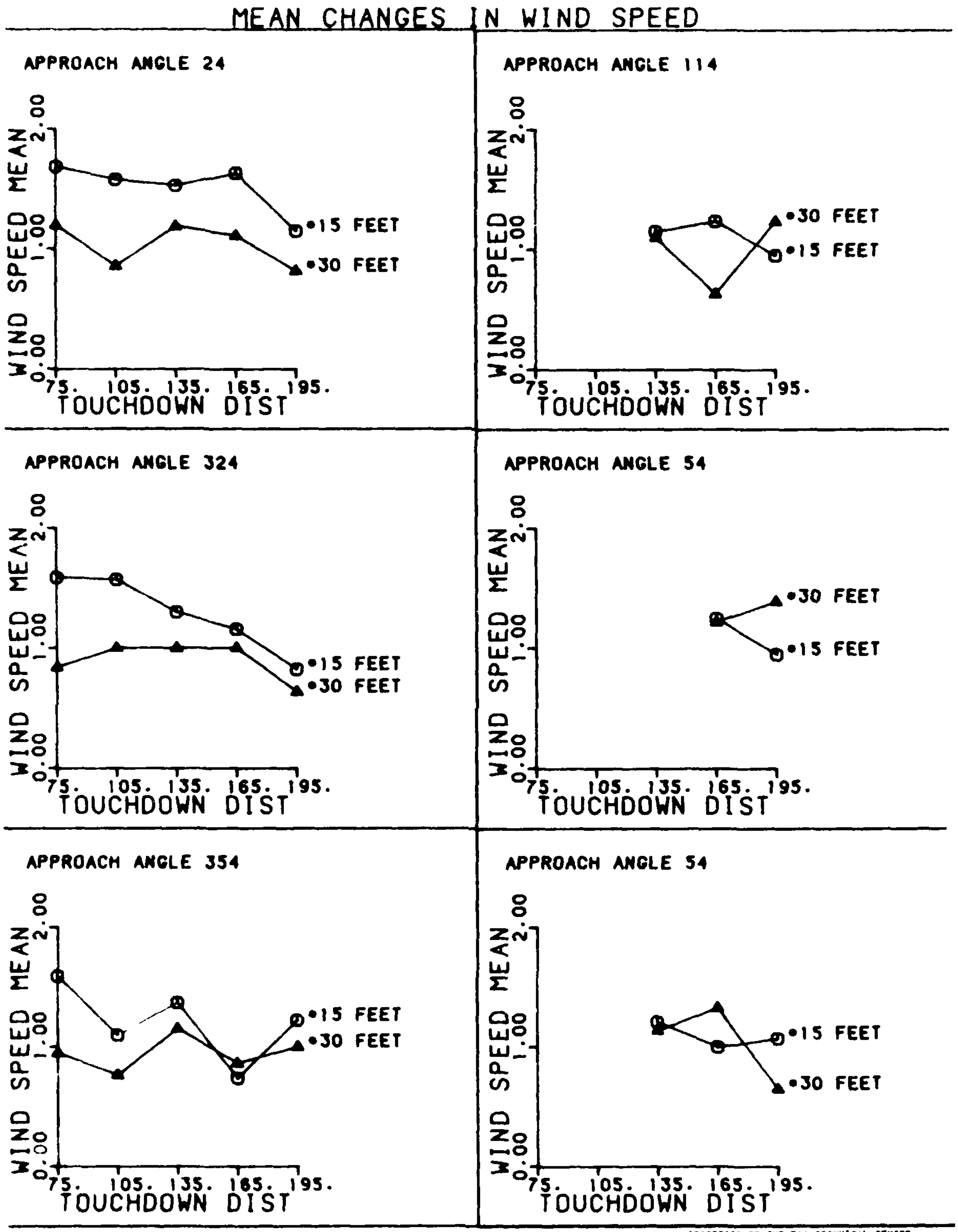


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FIGURE D-[illegible]. MEAN CHANGES IN WIND SPEED TOUCHDOWN DISTANCE AND APPROACH AZIMUTH

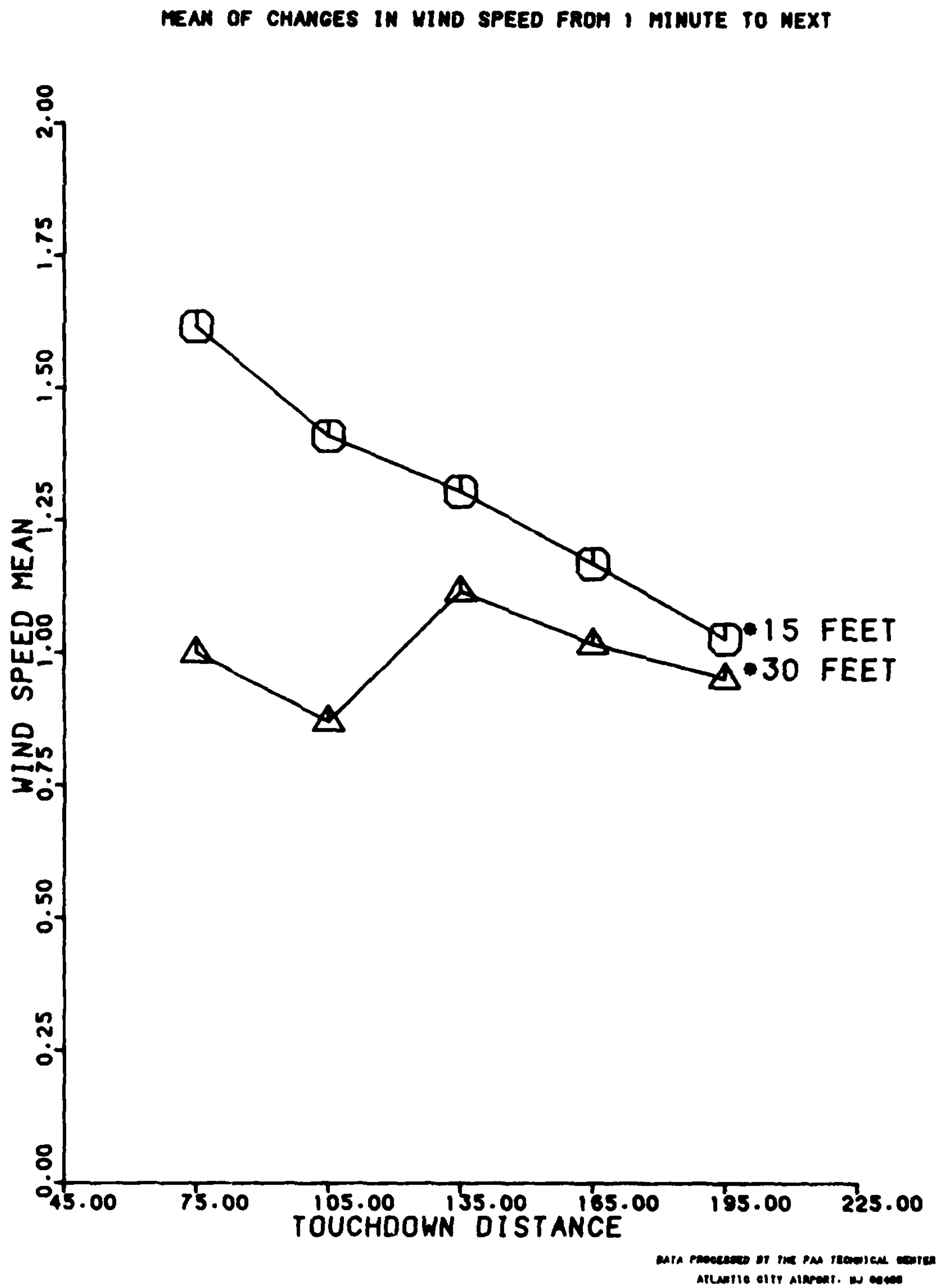

FIGURE D-5. MEAN CHANGES IN WIND SPEED TOUCHDOWN FROM ONE MINUTE TO NEXT TOUCHDOWN DISTANCE ONLY

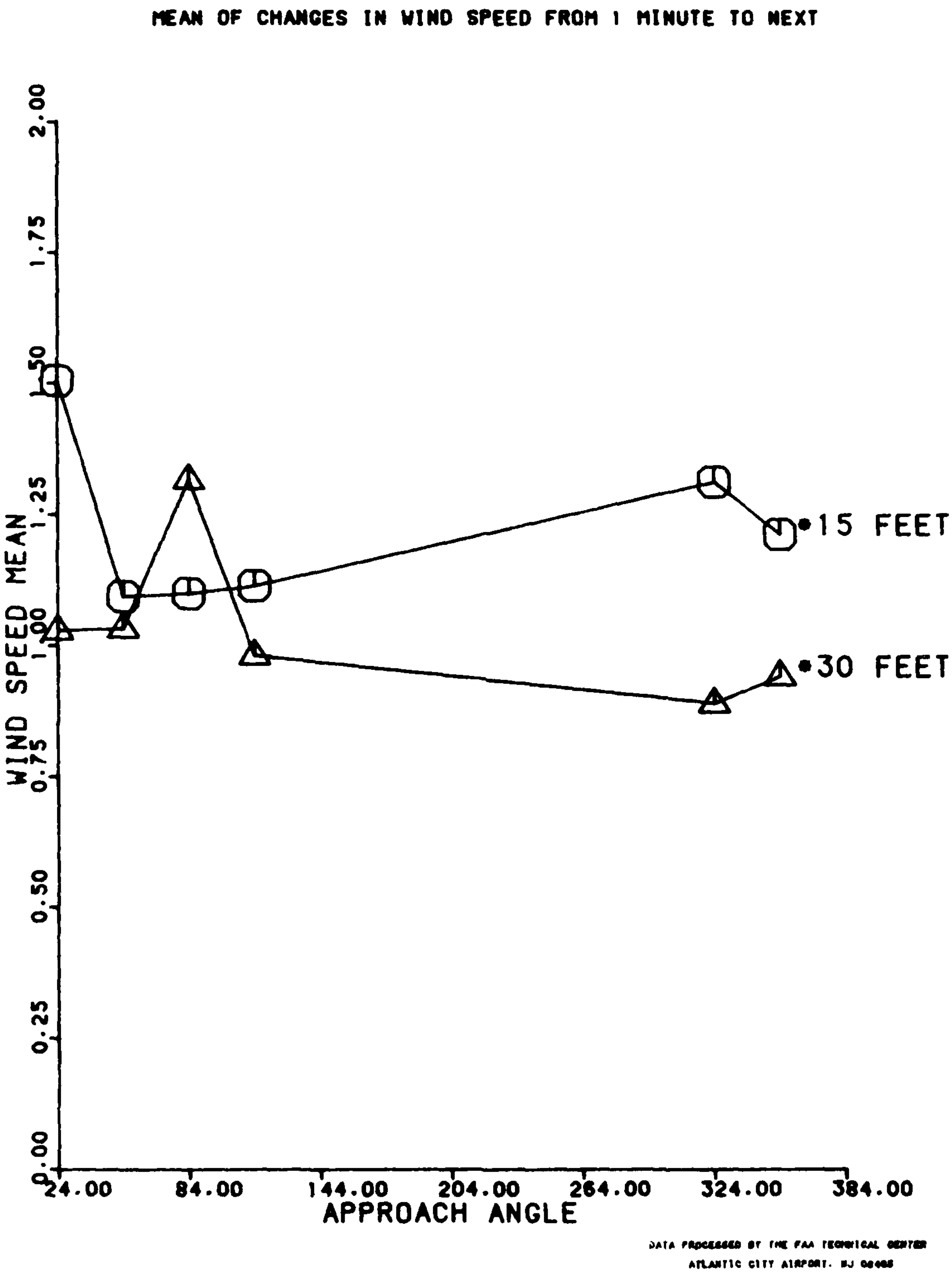

FIGURE D-6. MEAN CHANGES IN WIND SPEED APPROACH AZIMUTH ONLY

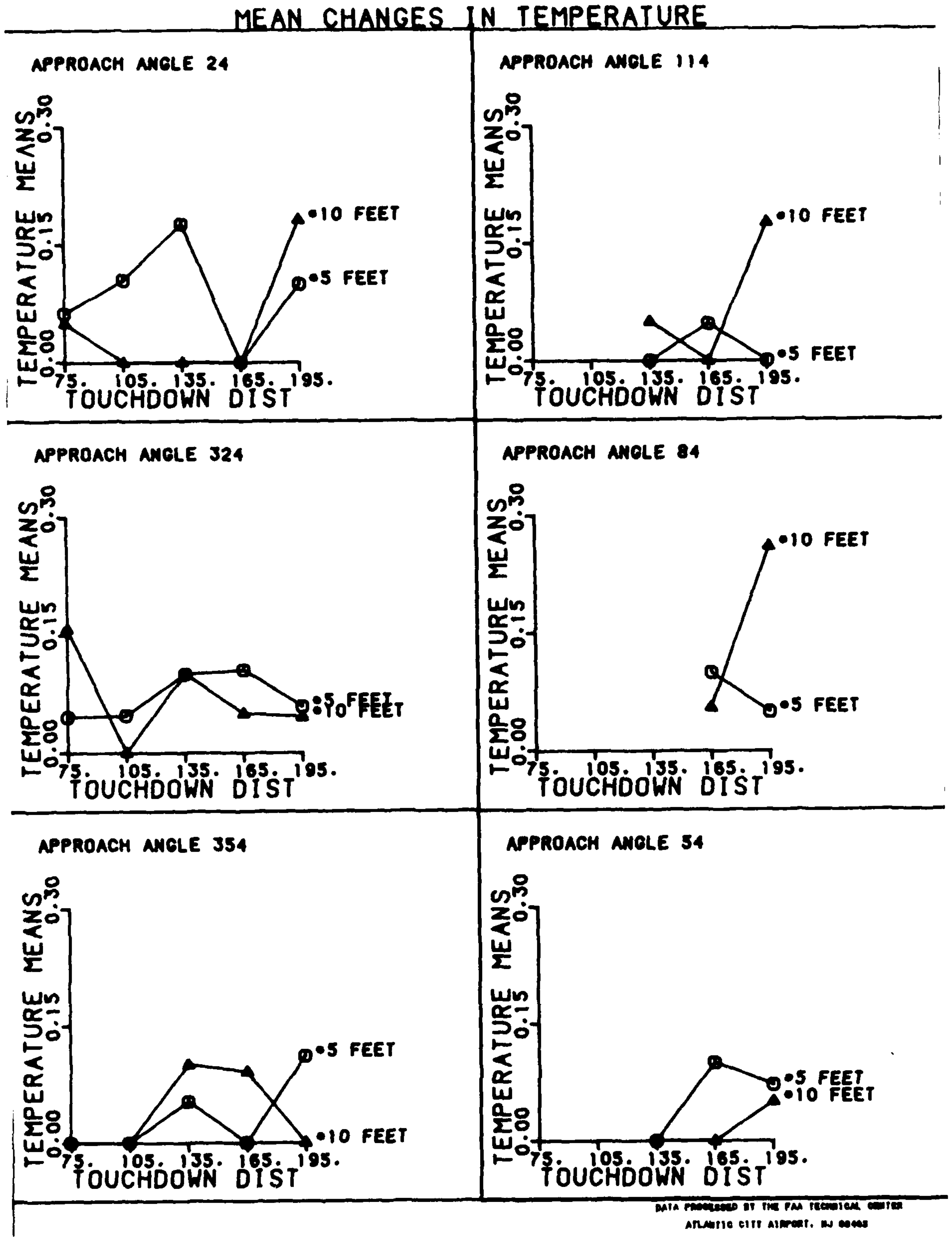

FIGURE D-7. MEAN CHANGES IN TEMPERATURE TOUCHDOWN DISTANCE AND APPROACH AZIMUTH

APPENDIX E

AWOS QUESTIONNAIRE

OPERATIONAL PILOT QUALIFICATIONS

NAME:

AFFILIATION:

ADDRESS:

CITY: STATE: ZIP:

ACTUAL HELICOPTER IFR HOURS:

HELICOPTER HOURS LAST 6 MONTHS

PERIOD OF FAA FLIGHT TESTS:

1. How far from the heliport were you when you received the weather information?

2. How accurate to you feel the wind direction and speed report is:

   If poor, explain why if possible.

   I----I----I----I----I
   1 2 3 4 5
   Poor Fair Excellent

3. Rate the overall system:

   I----I----I----I----I
   Poor Fair Excellent

4. Rate the suitability of AWOS for heliport operations?

   I----I----I----I----I
   Poor Fair Excellent

5. Rate the location of AWOS?

   If poor, explain why if possible

   I----I----I----I----I
   Poor Fair Excellent

6. Compare the AWOS Ceiling and Visibility report with actual observations experienced during flight.

Ceiling reported - feet, actual observation - feet;
Visibility reported - miles, actual observation - miles.

7. What did you like best about the AWOS?

8. What did you like the least about the AWOS?

9. Was there any increase in your workload?

10. What additional information would you want for heliport installations?

11. (Optional) Please feel free to comment further.

APPENDIX F

MAINTENANCE PROCEDURES AND INTERVALS

The following are manufacturers' recommended maintenance procedures and maintenance intervals for AWOS equipment. Maintenance intervals are given in Manufacturer/Technical Center format. Technical Center additions to manufacturers recommendations for heliport installations are preceded by "*".

1. Wind Sensor.

   a. Check propeller screw for tightness . . . . .90/90 days

   b. Check connector tightness . . . . .90/90 days

   c. Check mounting screw tightness . . . . .90/90 days

   d. Check entire assembly for physical damage . . . . .90/90 days

   e. Lubricate "water-repelling" felt washer with 1 or 2 drops of light oil. . . . . .90/90 days

2. Aspirated Radiation Shield.

   a. Check for airflow through the shield. . . . . 0/90 days

   b. Clean air intake. . . . . .90/90 days

3. Dew Point Cell.

   a. Check dewpoint accuracy against psychrometer . . . . 30/30 days

   b. Clean and retreat with lithium chloride solution. . . . . 90 days or less as required/same

4. Temperature Probe.

   a. Wipe off any contamination . . . . 90/90 days

5. Precipitation Gage.

   a. Remove and clean upper funnel screen of any debris, i.e., sticks, spider nests, etc. . . . . 90/30 days

   b. Remove outer cover, inspect and remove any insects and/or nests . . . . 90/30 days

   *c. Remove outer cover and clean tipping buckets of any dust, dirt or sand. . . . . 14 days or less in dry, windy and/or dusty environments.

6. Backscatter Visibility Unit.

   a. Check blower input filter, clean or change as required . . . . 30/30 days

   b. Check blower output by placing hand over output orifice. . . . . 30/30 days

   c. Check lens for cleanliness. . . . . 30/30 days or less

   d. Check exterior and flexible ducts for any deterioration or damage and correct as required . . . . 90/90 days

   e. Using monitor indicator model 83441 or model 83334, check for any significant deterioration of outputs from last check or any trend since installation . . . . .30 days

7. Cassette Tape Recorder.

   a. Check tape switch light bulbs . . . . .30 days

   b. Clean tape heads. . . . . .90 days

8. Printer.

   a. Change ribbon . . . . 90 days or less /dependent on frequency of printout

   b. Lubricate as required in manual. . . . . .90/90 days

9. Signal Conditioning Module.

   a. Check and readjust HI and LO calibration values as specified in manuals . . . . .90/90 days

10. Junction Boxes.

   a. Replace desiccant packs. . . . . .90/90 days

   b. Check for weatherproof seal around doors and cable glands. . . . . .90/90 days

   c. Inspect lightning protection devices . . . . .90/90 days
   *and after lightning activity.

11. <u>ASEA Ceilometer</u>.

a. Clean the transceiver windows. . . .   . Determined by local conditions/same

b. Replace high pressure fan filter . . . . 8-12 months or as determined by local conditions/same

c. Inspect and replace desiccant cartridge. . . . .   when color goes from dark to light blue /same

APPENDIX G

ANALYSIS OF VARIANCE (ANOVA)

Analysis of variance is a group of statistical techniques used to divide or partition total experimental variation into specific sources of variation. It is a flexible method of constructing statistical models for the explanation of experimental results.

The form of the model which is used can be expressed as:

> Observed value = parameters representing assignable effects +
> random variables representing assignable effects +
> random variables representing unassignable (residual)
> effects

Assignable effects mean those effects resulting from the operation of changes in recognizable or controlled conditions. For this experiment there are a number of factors such as approach angle, touchdown distance, and sensor height which might effect the observations. These factors are recognized formally prior to the actual experiment and correspond to assignable effects. The residual variation (error) contains elements which are not accounted for by the assignable effects but are usually of lesser importance.

Certain assumptions are made about the random variables:

1. The expected value of each residual random variable is zero.

2. The residual random variables are mutually independent.

3. The residual random variables all have the same standard deviation.

4. The residual random variables are each normally distributed.

The analysis of variance table (ANOVA) is derived in the following manner. The first column contains the sources of variance (SV). In the case of a three-factor design the sources are: main effect of each factor, 3 two-way interactions, and 1 three-way interaction. The second column contains the degrees of freedom (df) associated with each SV. The degrees of freedom equals the number of independent observations which is the total number of observation minus the number of restrictions on the observations. The third column contains the sum of squares (SS) of the observations for the SV about the total mean, while the fourth contains expected mean squares (MS) of the errors.

An F value is a statistic which is the weight ratio of the main effects of interaction sum of squares to the error sum of squares for the main effect or interaction being tested for significance.

The F value in the table is compared to a critical F. This critical F is determined from a standardized F table which can be found in any statistics textbook. The critical F is based on the degrees of freedom of the effect or interaction and the error degrees of freedom.

The following table summarizes the analysis of variance for the 3-factor incomplete design case:

Source of Variance (SV)	Degrees of Freedom (df)	Sum of Squares (SS)		Mean of Squares (MS)	F
Main Effects					
A (Row)	a-1	SS_A	(1)	SS_A/df_A	MS_A/MS_{error}
B (Col.)	b-1	SS_B	(2)	SS_B/df_B	MS_B/MS_{error}
C (Effect)	c-1	SS_C	(3)	SS_C/df_C	MS_C/MS_{error}
Interactions					
AB	(a-1)(b-1)-X/c	SS_{AB}	(4)	SS_{AB}/df_{AB}	MS_{AB}/MS_{error}
AC	(a-1)(c-1)	SS_{AC}	(5)	SS_{AC}/df_{AC}	MS_{AC}/MS_{error}
BC	(b-1)(c-1)	SS_{Bc}	(6)	SS_{BC}/df_{BC}	MS_{BC}/MS_{error}
ABC	(a-1)(b-1)(c-1)-X/c	SS_{ABC}	(7)	SS_{ABC}/df_{ABC}	MS_{ABC}/MS_{error}
	Total n- (abc-X)	SS_{error}	(8)	SS_{error}/df_{error}	

Where a is the number of rows; b, the number of columns; and c, the number of effects:

(1) $SS_A = \dfrac{\sum^{a}(\sum^{b}\sum^{c} y.)^2}{\text{Total n over all rows}}$ = - COR where $\sum^{a}(\sum^{b}\sum^{c} y.)^2$ = Total sum of squares of observations over rows regardless of columns or effects

(2) $SS_B = \dfrac{\sum^{b}(\sum^{a}\sum^{c} y.)^2}{\text{Total n over all columns}}$ = - COR

y, means all observations in the desired set

(3) $SS_C = \dfrac{\sum^{c}(\sum^{a}\sum^{b} y.)^2}{\text{Total n over all effects}}$ = - COR

(4) $SS_{AB} = \dfrac{\sum^{a}\sum^{b}(\sum^{c} y.)^2}{\text{Total n over row + column regardless of effect}}$ = - COR-SS_A-SS_B

(5) $SS_{AC} = \dfrac{\sum^{a}\sum^{c}(\sum^{b} y.)^2}{\text{Total n over row + effect regardless of column}}$ = - COR-SS_A-SS_C

(6) $SS_B = \dfrac{\sum^{b}\sum^{c}(\sum^{a} y.)^2}{\text{Total n over all columns + effect regardless of row}}$ = - COR-SS_B-SS_C

(7) $SS_{ABC} = \dfrac{\sum^{a}\sum^{b}\sum^{c}(y.)^2}{\text{Total n over row + column and effect}}$ = - COR-SS_A-SS_B-SS_C-SS_{AB}-SS_{AC}-SS_{BC}

(8) $SS_{error} = \sum^{a} \sum^{b} \sum^{c} y^2_{\cdot} \quad - \quad \dfrac{\sum^{a} \sum^{b} \sum^{c} (y_{\cdot})^2}{n \text{ in each cell}}$

COR = $\dfrac{\text{Sum of all observations squared}}{\text{total \# of observations}}$

X = number of empty cells

*See reference 2 and 3

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